FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by C. W. SCOTT

VOLUME XXIII : NUMBER 2

Price
Seven Shillings and Sixpence

Published by the
OXFORD UNIVERSITY PRESS
LONDON: GEOFFREY CUMBERLEGE
AMEN HOUSE, E.C. 4
1950

NOTICE

MR. R. W. V. PALMER has succeeded Mr. C. W. Scott as Editor of *Forestry*. All communications for the Editor should be addressed to Mr. R. W. V. Palmer, Bannerleigh, Leigh Woods, Bristol.

An Index for Vols. XI to XX of *Forestry* has been prepared and will go to press shortly. Its price and date of appearance will be announced later.

NOTICE

The price of *Forestry* will be raised to 12*s*. 6*d*. net per number as from Volume XXIV, Number 1

FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by C. W. SCOTT

VOLUME XXIII, No. 2

Published by the

OXFORD UNIVERSITY PRESS

LONDON : GEOFFREY CUMBERLEGE

AMEN HOUSE, E.C. 4

1950

CONTENTS

Tree Breeding and Seed Supplies in North-West America with special reference to Douglas fir (*Pseudotsuga taxifolia* Brit.). By H. G. CHAMPION 69

Interim note on a Thinning Study in Young Pine in East Anglia (*Pinus sylvestris* L. and *Pinus nigra* var. *calabrica* Schneid.). By F. C. HUMMEL 78

The Soil Conditions which determine Wind-Throw in Forests. By W. R. DAY 90

An Example of Periodic Variation in Forest Sampling. By D. J. FINNEY 96

The Resistance of Wood-Rotting Fungi to Desiccation. By W. P. K. FINDLAY 112

Society's and Other News 116

Annual Excursion of October 1949, Based on Hereford 117

REVIEWS

Dartington Hall Woodlands, Ltd. An examination of the accounts for the year 1947–8 (W. E. HILEY). By J. J. MACGREGOR 123

The Forests of Present-day Finland (YRJÖ IKVESSALO). By H. M. STEVEN . 125

NOTICES

The Forest Economy of Three Private Estates in Great Britain. By J. J. MACGREGOR 127

The Establishment of Vegetation on Industrial Waste Land. By R. O. WHYTE and J. W. B. SISAM 127

Quality of Second-Growth Douglas-Fir and Suggested Means of Improvement. By BENSON H. PAUL 127

State Control of Private Forestry under European Democracies. By M. L. ANDERSON 128

Y Coedwigwr ('The Forester') (University College of North Wales, Bangor) 128

SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

The membership is divided into four classes, the respective qualifications being as outlined below:

FELLOWS: Subjects of the British Crown fulfilling all four of the following requirements: (1) A degree or diploma in forestry, &c. (2) Five years of practical experience in forestry, &c. (3) Having been a Professional Associate for 5 years. (4) Having had a thesis or published article approved by the Council. Annual subscription £1. 11*s.* 6*d.* (Twenty-five guineas for life.)

PROFESSIONAL ASSOCIATES: Subjects of the British Crown fulfilling any one of the following requirements: (1) A degree or diploma in forestry, &c. (2) Having made important contributions to forestry, &c. (3) Considered by the Council to occupy a post normally held by a holder of a university degree in forestry. Annual subscription £1. 1*s.* 0*d.*

PROFESSIONAL MEMBERS: Subjects of the British Crown resident in Great Britain, engaged whole time in forestry but not eligible for above classes. Annual subscription 10*s.* 6*d.*

ORDINARY MEMBERS: Persons or corporate bodies not eligible for any of above classes. Annual subscription £1. 1*s.* 0*d.*

Fuller details of qualifications may be obtained from the Secretary.

Only Fellows are eligible for the higher offices and for most seats on the Council, but one Councillor may be a Professional Associate and one a Professional Member. Office bearers and Councillors are selected by written nomination and postal ballot. Fellows and Professional Associates have full voting rights, but Professional Members have only limited voting rights.

Office-bearers and Councillors in 1948–9

President: O. J. SANGAR, M.C., Director of Forestry for England.

Vice-President: PROF. H. M. STEVEN, M.A., PH.D., Department of Forestry, University of Aberdeen.

Editor: C. W. SCOTT, O.B.E., D.F.C., B.SC., 31 Tindal Road, Aylesbury, Bucks.

Business Editor: J. A. B. MACDONALD, DIP. FOR., 35 Manor Place, Edinburgh, 3.

Secretary and Treasurer: R. A. GALLOWAY, M.C., B.SC., Solicitor, 8 Rutland Square, Edinburgh, 1. Tel. No. Edinburgh 23842.

Auditor: D. L. FERGUSSON, 25 Drumsheugh Gardens, Edinburgh, 3.

Councillors: W. H. GUILLEBAUD, B.A. (Immediate Past President); A. H. GOSLING, B.SC.; RAY BOURNE, M.A. (Died 30th Nov. 1948); B. J. RENDLE, B.SC.; J. L. HARRISON, I.F.S. (retired), M.I.B.A.E.; BRUCE URQUHART, B.A., F.L.S.; C. A. CONNELL, B.A.; A. P. LONG, O.B.E., B.A., DIP. FOR., DIP. AGRI.; H. C. BERESFORD-PEIRSE, B.A., B.SC.

THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

THE SOCIETY'S JOURNAL, called *Forestry*, is usually published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to R. W. V. Palmer, Bannerleigh, Leigh Woods, Bristol. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Each article should conclude with a summary, not exceeding 3 per cent. of the original. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh, 1.

SOCIETY'S MEDAL. This may be awarded by the Society to any individual who has rendered eminent services to British forestry. Proposals for the award have to be made in the first instance to the Council by a Member of the Council. The regulations for the award will be found in Vol. xx, pp. 80, 81, and in Rule 11.

TREE BREEDING AND SEED SUPPLIES IN NORTH-WEST AMERICA WITH SPECIAL REFERENCE TO DOUGLAS FIR (*PSEUDOTSUGA TAXIFOLIA* BRIT.)

By H. G. CHAMPION

(*Department of Forestry, University of Oxford*)

IN August and September 1948 an opportunity was generously made available by the Dartington Hall Trustees for Mr. W. E. Hiley and myself to visit the Pacific coast of North America to study developments in forestry over the war years. This tour provided the material for a short series of notes on certain major topics, of which this article on tree breeding is one.

It would justifiably be expected from the large extent of natural forest in the region a few hundred miles north and south of Puget Sound, and from the ease with which second growth usually springs up after logging, that there would be little interest in artificial regeneration; and consequently little interest in the collection, quality, and possible improvement of seed, even of the common species, viz. Douglas fir (*Pseudotsuga taxifolia* Brit.), Sitka spruce (*Picea sitchensis* Carr.), western hemlock (*Tsuga heterophylla* Sarg.), and western red cedar (*Thuya plicata* D. Don). It is true that until quite recently very little sowing or planting had been attempted, but the growing realization that it is not possible to continue to disregard the vast loss of production and site deterioration of logged-over areas has stimulated interest in the matter. Destructive of immature growth as some of the logging, notably high-lead logging, has been, the real destroyer has been fire. Fire has swept through the second growth, killing it outright and with it usually also any residual actual or potential seed trees, which, given time enough, might have reseeded the area. The extent of former forest land which is more or less devoid of regeneration owing to such fires is vast, and methods of restoring these wastes have to be easy and cheap to be undertaken. Sowing might appear to be a better proposition than planting, but experience has shown that planting is preferable, and it is now being carried out on a fairly extensive scale both by the Forest Services and private owners; and nurseries are being made to supply the stock. Hitherto by far the greater part of the work has been done with Douglas fir, though the associated commercial species and *Chamaecyparis lawsoniana* Parl. have been used to a small extent.

In the circumstances it is not surprising that in Britain we have more experience in handling these west coast species in the nursery and planting area than have the local American and Canadian foresters. This work is being discussed elsewhere by Mr. Hiley, my companion on the visit made in August–September 1948 to the western states and British Columbia, our special object being to collect any information about the species mentioned that might be useful, directly or indirectly, in afforestation work in Britain. This article will deal

only with what we saw and heard relating to the quality and availability of seed supplies.

In view of the above considerations it is a matter for congratulation that already by 1912 the question of the effect of provenance of Douglas fir seed was being taken up in a fairly large-scale experimental investigation at the Pacific Northwest Forest Experiment Station at Wind River, in Warlington, near Carson, 45 miles up the Columbia River from Portland. This experiment was planned on lines not very dissimilar from those adopted somewhat earlier for *Pinus sylvestris* L. in Europe. The basic idea was to collect seed from a number of stations scattered over the natural geographical and altitudinal distribution of Douglas fir (unfortunately for us, only from western Oregon and western Washington), and to study performance of planting stock raised from this seed at a number of stations, likewise varying in position and altitude. Unlike most of the European provenance experiments referred to, this investigation kept the progeny of individual cone parent trees separate, and specifically provided for two or more classes of tree-age, freedom of crown, site quality, and soundness. It was hoped that it would be possible later on to analyse the effect of each of these factors on the development of the progenies, as well as the effect of provenance. The value of such information is obvious, for determining what may be expected from trees of different types left standing on felled-over areas, whether retained deliberately for reseeding or left as unmerchantable.

In all such experiments one realizes now that one might have got much more useful information for the same amount of labour and time, had the parent trees been rather differently selected, and had the planting out been done on lines which have been developed since those early days; but this investigation is none the less the most instructive in existence for Douglas fir. Fairly full accounts have been published in U.S. Dept. of Agri. Techn. Bull. 537 (1936) (2) and in a mimeographed summary by T. T. Munger and W. G. Morris, dated 10th April 1942, so it is unnecessary to go into detail here.

The seed collected in 1912 came from 125 trees, from thirteen localities varying in altitude from 100 to 3,850 feet. Seedlings were raised in Wind River nursery in the Cascade Mountains, at 1,100 feet, and distributed in 1915 as 2+0 year stock to six experimental plantation areas varying in altitude from 1,100 feet at Wind River to 4,600 feet on Mt. Hood, and including one, Siuslaw, only 10 miles from the ocean. There was enough stock for 10–100 (average 20) plants of each progeny, and a smaller replication with stock from the same seed was made in the following year.

There have been the usual mishaps with fire and pests, but eight of the twelve plantations survive, and data are available up to 1941. We were glad to be able to visit the Wind River replication, as the recorded data do not include information on branching habit, natural cleaning of stems, bole form, &c. These features are of much practical importance, but difficult to assess objectively.

As most other similar investigations have shown, within any one origin there were no significant differences ascribable to age of parent tree and soundness or density of parent crop (crown development); and no effect due to the soil quality

on which the parent tree grew could be demonstrated. Susceptibility to attack by *Rhabdocline* showed some variation with provenance but greater differences between individuals of the same provenance. Juvenile mortality showed no relation to origin.

Again in conformity with general experience and theoretical expectations, the relative performance of the different origins is not the same on the different planting sites; but one of the most interesting indications of the whole investigation is that certain origins are among the best in several stations, despite the difference of conditions between the latter. In other words these origins are not only inherently good under one set of conditions but they are sufficiently adaptable to show comparable good development under different conditions. The Palmer (Oregon, east of Portland, 2,000–3,000 feet) origin is an illustration of this, being one of the quickest growers inland, at 1,100 feet and at 2,800 feet, and also at the coastal station, Granite Falls (Washington, east of Seattle, 500 feet), where it has behaved similarly. In respect of good form, with light branching, the Darrington origin (Washington, north-east of Seattle) is noticeably above average, though on height and diameter growth it is not outstanding. We were told that this origin has been tried in Britain, but we have not been able to get further particulars. Other noteworthy points are that the high-altitude origins have so far shown the best diameter growth at the high-altitude plantation, and that, in marked contrast to the usual experience, at Wind River the local origin has given the poorest result of all.

From the point of view of the British forester it is a pity that more northerly origins, notably Fraser River and Vancouver Island, are not included in this series. Apart from the general indications referred to above, it would appear that if it is procurable, seed from Darrington and from Palmer or Granite Falls would be worth including in any future trials in this country, but as will be shown later, it should come from selected stands in those localities.

It is of interest to note that scions from narrow and wider branching Douglas firs growing at Wind River, grafted on stocks in Denmark by Dr. Syrach Larsen, already show comparable differences in branching in the first season of growth.

Reference will be made later to the valuable tree-breeding work done at the Institute of Forest Genetics, Placerville, N. California. This Institute is not at present doing much on Douglas fir, but when it was started in 1925 material was gathered for study from a much wider range of stations than at Wind River. After a few years, however, it was decided to concentrate on the genus *Pinus*, and the Douglas fir stock was reduced to a few individuals of each provenance, transplanted to a strip along the edge of the experimental plantation area. Placerville is climatically so unlike Britain that the performance of different origins there would be no guide for us, but we made one observation which seemed worth following up with regard to susceptibility to *Adelges cooleyi* Gillette. This insect was present in varying though usually small numbers on many of the trees. One or two trees, however, were fairly heavily infested, yet adjoining trees whose branches intermingled with those of the infected trees were almost or quite free of the insect. Differences of susceptibility, even within the 'green' forms, seemed

clearly indicated. Incidentally, the *Adelges* appears to do little harm to the Douglas fir in its natural home, and so has received very little attention from forest entomologists.

We did not see any comparative provenance studies with Douglas fir in British Columbia.

Although it is possible to collect viable Douglas fir seed in Britain, the bulk of our not inconsiderable requirement is imported. It was quickly discovered that seed from the pronouncedly continental parts of the range of the species was unsuitable for use in Britain. The contrast between the Colorado and coastal origins in experimental plantations now 40 years old in several places is extreme. Most of our best plantations have been raised from seed from the Lower Fraser valley, and for some years now the bulk of our seed indents have asked for this provenance.

Reference is necessary to a valuable paper by J. H. J. Gerlings, J. F. Smit, and J. van Soest (1) on the results of extensive Douglas fir provenance experiments from sowings of 1927–31 at a number of stations in Holland, with a review of older and current trials on the Continent. In Holland also the best results are with the 'green' Douglas from maritime climates, Lower Fraser valley origins making a particularly good showing (at 10 years of age), closely followed by some Washington origins, either from the coast or moderate distances inland. But in these tests again there are marked differences between the performances of origins which would be grouped together geographically and climatically.

Apart from several firms dealing in forest seed from the American west coast (e.g. Manning's and Company, and the Reed Seed Co. of Washington State, and others), the main source of seed has been MacFadyen's extraction plant on Lulu Island, near Vancouver City, now run by Mr. Roche. We were fortunate in finding Mr. Roche at the plant when we called, and also in being able to discuss the subject with Mr. MacFadyen, now retired on Vancouver Island. At this plant seed is extracted for the supplying organizations from cones sent in by the British Columbia Forest Service, the United States Forest Service, and their Experimental Stations; but Mr. Roche also has arrangements for collecting cones against other orders, especially those received from abroad. This is done through the agency of small farmers and others. The cones may be collected from trees felled in logging operations, but are mostly from second-growth trees, as they are easier to climb than virgin growth. Many cones are also collected from the ground after being dropped by squirrels. It will be realized that as there are no old plantations, all second growth will have originated from the natural forest and have the same genetic constitution, whilst the Wind River experiments demonstrate that there is no objection to seed from young trees.

Fortunately it is easiest and cheapest to obtain seed from the more accessible parts of the Lower Fraser valley and Vancouver Island, so there is very little likelihood of seed from other regions being mixed in. It might be thought that in years of poor local supply the plant might be tempted to draw on more distant and possibly less desirable sources, but we were assured that this was not done, and that any shortage tended to be general. The annual seed crop varies very considerably

with Douglas fir, and was very poor indeed in 1948, following a poor yield in 1947 but a heavy crop in 1946.

The Wind River experiments show that there may be quite significant differences in the development of stock from localities in one climatic region, no farther distant than the different parts of the territory drawn on for the Wind River plantation. They also support European experience that the progenies of individual trees within a provenance area may differ appreciably. Whilst the evidence thus indicates that the best seed is only obtainable from specifically selected stands and trees, it is not at present practicable to procure such seed.

The basic information is not available on which to select superior seed stands, and it would be difficult to guarantee origin under present conditions unless special arrangements could be made to collect the cones and extract the seed from them separately. This is what the Canadian and U.S. forestry organizations do. The difficulties of securing more than small experimental quantities from specific restricted areas (such as the best origins revealed by the Wind River experiment), or from selected stands or even trees, were emphasized. The expense would be very high, even if the task could be undertaken at all. The best approach for obtaining seed for research purposes would be to the U.S. Forest Service, Pacific North-west Forest Experiment Station for U.S. origins, and the Deputy Minister, Forest Service, Victoria, Vancouver Island, for Canadian origins. In each case arrangements would usually have to be made by them through the ranger in charge of the forests in question.

The only other of our species of which seed was being extracted at Lulu in any but small quantities was Sitka spruce (*Picea sitchensis* Carr.). The seed of this species all comes from the Queen Charlotte Islands, the handiest source for any large amount. There are nowhere provenance tests of any age for this tree, and the only relevant information we have is that stock from the southern part of the range is more frost-susceptible than stock from farther north. The Queen Charlotte stock appears to have given satisfaction so far in Britain, and being the easiest source of seed is likely to continue to be supplied, at least until some other origin is called for.

We were unable to make direct contacts with the other firms dealing in west coast tree seed but our inquiries led us to conclude that owing to the conditions under which the seed has to be collected, it would be most difficult to get supplies guaranteed to come from given sources.

There is no institution devoting special attention to forest tree-breeding in British Columbia, or in the two north-western states, but California has the oldest station set up specifically for this work. This station, now the Institute of Forest Genetics, owes its origin to a Seattle lumberman, J. G. Eddy, who won Luther Burbank's interest and advice, and set up a tree-breeding station at Placerville ('Hangtown' in the gold rush days) in 1925. It was gifted to the U.S. Forest Service in 1935, after a good start had been made, chiefly with pines. The early work was mainly on provenance and individual tree progenies, especially with yellow pine (*P. ponderosa* Dougl.). Attempts at hybridization were mostly unsuccessful. In 1940, however, hybridization work was taken up with vigour, and

a large number of pine hybrids have been obtained, some of them of considerable interest. As the species concerned are not much used here, only a few of these results—to be mentioned later—are of specific interest to Britain, but the general results and the fundamental principles demonstrated are of very considerable significance to foresters generally. It has been shown that as a rule hybridization of pines is relatively easy and the hybrids are fertile. The out-turn of seeds per controlled pollination bag is 5–200. One man can pollinate and bag 150–500 young cones a day, but including the whole series of operations involved, beginning with the search for suitable trees, the average out-turn is 25 bags per man per day. One can expect from the 25 bags ultimately about 500 hybrid plants, sometimes many more.

One of the first hybrids to be obtained was *P. radiata* D. Don × *P. attenuata* Lemm., and when I first visited the station in 1935 an interesting and significant result was already apparent. The hybrid grew faster than *P. attenuata* though not quite so fast as *P. radiata*, but whereas the latter was practically wiped out at Placerville by frost, the hybrid, like its other parent, was hardly affected.

The station now has thirty interspecific pine hybrids, seven of them as F_2. In one series of twelve F_1 crosses, four definitely show hybrid vigour exceeding both parents in growth, and several others are promising. One of the clearest cases is *P. monticola* D. Don × *P. strobus* L. (well shown in Fig. 6 of U.S.F.S. Misc. Pub. No. 659 (3) at 4½ years old), where the hybrid is twice as tall and three times as heavy as the better parent; *P. monticola* × *P. excelsa* Wall. and *P. strobus* × *P. excelsa* show similar behaviour. Promising hybrids include those between *P. ponderosa* Dougl. and the rather similar species, or perhaps only varietal forms, *P. scopulorum* Engelmann and *P. apacheca* Lemm., whereas crosses of geographical races of *P. ponderosa* do not show hybrid vigour, that feature being attached, apparently, to crosses between closely related species. The hybrid between *P. banksiana* Lamb. and *P. murrayana* Balf. (lodgepole) has the good form of the latter and the much more vigorous growth of the former, and so should be of value wherever either or both species grow or can be grown.

Of particular interest is the search after a good five-needled pine resistant to blister rust, but Dr. Syrach Larsen has perhaps already got such a form in *P. peuke* Griseb. × *P. strobus* L., and it is hoped to duplicate this hybrid with his help. Comparable interest and value attaches to some crosses involving *P. jeffreyi* Grev. and *P. coulteri* D. Don, showing greater vigour than *P. jeffreyi* (or *P. ponderosa*), together with resistance to insect attacks, though timber quality and frost resistance remain to be determined.

The question of the application of these discoveries to large-scale practice has not been neglected, in fact quantity production of hybrid seed has been the special assignment of one of the staff (J. W. Duffield), who accompanied us on most of our inspections in this neighbourhood. Effective methods of storing pollen have been found and a pollen 'bank' is maintained. The potentialities of controlled pollination have been mentioned above, and it has been pointed out that the hybrid stock can be tested out in the field without loss of space or time by inter-planting into normal stock. If the novelty under test is good, it will become

dominant and after a series of thinnings will come to form the greater part of the final crop. If it is not so good as the ordinary stock, it will merely drop out, with no harm done. The 500 hybrid plants that can result from one day's work on cross-pollination will suffice for 2½ acres if spaced out at the rate of 200 per acre among ordinary stock. Usually the hybrids are fertile, and F_2 will contain enough individuals with the good characteristics of F_1 for natural regeneration to be acceptable. Moreover, the seed from the F_1 trees, including back crosses, would yield a usable percentage of superior trees for further plantation work.

Experience at Placerville thus indicates that the best prospects of a valuable first cross exist when one crosses two species which are taxonomically closely related but geographically widely separated, as illustrated by the hybrids between the eastern and western white pines and between jack and lodgepole pines, already mentioned.

So far, only a limited amount of work has been done on vegetative propagation for quick multiplication of selected stock, and to date at least it has proved very expensive.

Summarizing the general position in this matter of tree breeding, western America provides much weighty evidence that valuable new forms are obtainable from hybridization, some of them possessing greatly increased growth vigour, together with innate resistance to adverse locality and biological factors. These forms are obtainable with reasonable certainty in a quite short time and at moderate cost, and can be produced in quantity as soon as their value has been recognized and a demand for them arises. The increase in volume production may be up to 200 per cent., as compared with, say, 25 per cent. from isolated *élite* races of the parent species.

As noted, the Placerville Institute has been concentrating for some time for very good reasons on the pines; but the possibility of an extension of the work to other genera is being considered. In *Pseudotsuga*, species hybrids do not appear to enter into the picture, though the hybrid *P. taxifolia* Brit. × *P. macrocarpa* Mayr. has recently been obtained and is under observation. The chief desiderata are vigorous growth, good form with light branches, and resistance to *Adelges* attack. These features are most likely to be found by provenance and progeny studies, followed by controlled pollination between selected good individuals of the best provenances for given site types. There are indications that such crossing may well give extra vigorous progeny, but the gain is not likely to be so marked as with some interspecific hybrids. Among the other important west coast species it may be noted that Sitka spruce is already known to hybridize readily with several other species, e.g. *Picea alba* Link, *engelmannii* Engelm., *excelsa* Link, *omorica* Bolle, and there is certainly room for research, with good prospects of useful results.

What bearing has all this on what we might be doing in Britain? Clearly, provenance of Douglas fir is of considerable practical importance and insufficient attention appears to have been paid to the exact source of seed used here. The chief defect is that in most cases, owing to lack of exact information, it is usually impossible to get more seed guaranteed to be of the same provenance as a lot

which has shown superiority in Britain. Even when the origin is known precisely enough, the parent stand may no longer exist. In view of the labour involved in laying out provenance experiments, and the long time likely to elapse before comparison can be made with confidence, more care is called for in selecting parent stands and ensuring as far as possible that it will be possible to obtain further seed supplies of any progeny that shows itself superior. A co-operative experiment between the U.S. Pacific North-west Forest Experiment Station, the British Columbia Forest Service, and the Forestry Commission in Britain, in which the two former would arrange the seed supply, should be of value to all parties. Progeny tests on seed from *élite* parent trees within an origin, and controlled pollination between selected individual parents can fairly be left to workers on the west coast, but the closest touch should be kept with developments in this field.

In conclusion, I wish to acknowledge very gratefully the kindness of Mr. C. D. Orchard, Deputy Minister, Forest Service, British Columbia, and of Mr. Stockwell,* of the California Forest and Range Experiment Station, Berkeley, and Mr. Isaac, Pacific North-west Forest Experiment Station, Portland, Oregon, in reading the original draft of this article, and suggesting various amendments which have been made.

SUMMARY

The developments in tree breeding and select seed supplies on the Pacific coast of North America are reviewed briefly. Particularly valuable work on Douglas fir (*Pseudotsuga taxifolia* Brit.) has been done since 1912 in Oregon at the Pacific North-west Forest Experiment Station, Wind River. Valuable work also is being done at the Institute of Forest Genetics, Placerville, N. California, mainly on the genus *Pinus*; and in their few Douglas fir stocks the author noted apparent marked differences in susceptibility to the insect pest, *Adelges cooleyi*, which, however, seems to do little harm to Douglas fir in its natural home.

There is evidence that there are important differences in the value of Douglas fir seed from specific stands or trees inside any one climatic zone, but at present it is not practicable to procure *élite* seed in quantity. For research purposes limited amounts may be obtainable by special arrangements.

The work on *Pinus* at Placerville is producing very promising fertile hybrids, with increased vigour and resistance to insects. Their timber quality and frost resistance have still to be determined. Controlled pollination by the use of bags is proving effective at 25 bags per man-day, yielding 500 or more hybrid plants. These can be tested by interplanting with ordinary stock, and leaving or removing the hybrids in thinnings, on their merits. Thus 2½ acres of diluted planting can be tried per man-day of bag-work. The possible increase in volume production is up to 200 per cent., compared with, perhaps, 25 per cent. by the use of *élite* natural races. A co-operative experiment in the latter technique is suggested, between the U.S. Pacific North-west Forest Experiment Station, the British Columbia Forest Service, and the Forestry Commission of Great Britain.

* Mr. Palmer Stockwell informs me that Professor A. J. Riker of the University of Wisconsin, Madison, Wisconsin, is making a most promising series of selection studies for blister rust resistance.

LITERATURE REFERENCES

(1) Gerlings, J. H. J., Smit, J. F., and van Soest, J.: 'Herkomstonderzoek van den Douglas-spar aan de Afdeeling Houtteelt van het Instituut voor Boschbouwkundigonderzoek.' *Ned. Boschb. Tijds.* 1939, 405–32.

(2) Munger, T. T., and Morris, W. G. *Growth of Douglas Fir trees of known seed source.* U.S. Dept. Agri. Tech. Bull. 537, 1936.

(3) *Tree Breeding at the Institute of Forest Genetics.* U.S. Dept. Agri., Forest Service, Misc. Publ. 659, 1948.

INTERIM NOTE ON A THINNING STUDY IN YOUNG PINE IN EAST ANGLIA

(*Pinus sylvestris* L. and *Pinus nigra* var. *calabrica* Schneid.)

By F. C. HUMMEL

(*Forestry Commission*)

INTRODUCTION

EVERY year large areas of Scots pine (*Pinus sylvestris* L.) and Corsican pine (*Pinus nigra* var. *calabrica* Schneid.) in East Anglia are reaching the stage when they must be thinned for the first time. The question of determining the most suitable type and severity of thinnings is therefore of some importance. In particular, answers must be found to the following questions:

1. What is the current annual increment of young pine plantations?
2. What thinning grade produces the maximum increment?
3. Are crown thinnings preferable to low thinnings?
4. What is the heaviest thinning that can be carried out while still leaving a useful main crop? (This question was of particular importance during the war, when it was essential to obtain the greatest possible immediate production by all means short of clear felling. It is of less importance now because current policy is governed by the need to build up as rapidly as possible stocks of timber of all sizes.)
5. How does the mechanical removal of whole rows of trees compare with silvicultural thinnings:
   (*a*) in its effect on increment?
   (*b*) in its effect on the general development of the main crop?
6. How much is the yield from thinnings likely to be, under various thinning grades?

The first sample plots in East Anglian pine stands were established in 1939. Others followed in 1941, 1942, and 1943. The period of observation is obviously too short to produce definite answers to these questions; but as the problem is urgent it may serve a useful purpose to examine the results to date, in order to see whether they can be of some slight help to those who have to decide on the thinning policy for the immediate future, and also in order to obtain a clearer picture of future research requirements in connexion with thinnings in the pine plantations of East Anglia.

HISTORY AND SITUATION

The large-scale planting of pine in Suffolk and Norfolk by the Forestry Commission dates back to 1922. Since then some 40,000 acres have been planted upon land that was formerly rough grazing or rabbit warrens. Of these 40,000 acres rather more than one-half are Scots pine (*Pinus sylvestris* L.) and the remainder

Corsican pine (*Pinus nigra* var. *calabrica* Schneid.). Both species are normally planted pure, at a spacing of 4½ feet, but mixtures with beech (*Fagus sylvatica* L.) have been tried on a small scale.

The land is of a uniform character, gently undulating, with elevations of 25–200 feet above sea-level. Rainfall is low, averaging 20–25 inches per annum. The underlying subsoil is chalk, covered with sand to a varying depth of around 1 foot. The easy nature of the ground, together with the excellent natural drainage, renders the extraction of thinnings easy because wheeled vehicles can travel over most of the straight rides which intersect the area.

Sample Plots (Table I).

(*a*) *Scots pine* (*Pinus sylvestris* L.). Thirteen Scots pine plots have been established, in five localities, as indicated in Table I. Eleven of these plots are in the 1922 to 1925 planting areas and their top heights (height of 100 largest trees per acre) range from 28½ to 33 feet at 20 years. The remaining two plots are at Brandon Park, in naturally regenerated stands dating back to about 1907. Their top heights at 20 years were only 19½ to 23½ feet, but this smaller top height may be due to the slower initial height growth of naturally regenerated pine and not to inferior site conditions. The thinning grades employed in the thirteen plots are:

A	grade	(unthinned, except for the removal of dead stems)	3 plots
B	,,	(light low thinning)	0 ,,
C	,,	(moderate low thinning)	0 ,,
D	,,	(heavy low thinning, 600 stems per acre at 20–25 years)	4 ,,
D++	,,	(very heavy thinning, 300–350 stems per acre at 20–25 years)	3 ,,
L.C.	,,	(light crown thinning)	3 ,,
		Total	13 plots

Three plots of these thirteen, the L.C. and D grade plots at Broomhouse and the D++ plot at Swaffham, have had to be abandoned owing to damage by *Fomes annosus* Fr. It is interesting to note that in the same localities the unthinned plots, which are situated very close to the abandoned ones, are still intact and have suffered hardly any casualties. (See *Forestry*, vol. xxii, no. 2, 1948, for an article on this fungus in this area, by Mr. J. Rishbeth (3).)

It is unfortunate that comparisons between the thinning grades are incomplete because each grade is not represented in each locality and because some of the plots were remeasured at different times from the others. These deficiencies reduce the value of the past measurements for determining the effect of thinnings on the rate of growth.

(*b*) *Corsican pine* (*Pinus nigra* var. *calabrica* Schneid.). There are 14 Corsican pine plots, 3 at Rendlesham, 4 at Broomhouse, 4 at Swaffham, and 3 at Santon Downham, as shown in Table I.

The three plots at Santon Downham form a series apart, which was designed to compare the increment after D grade thinnings with that obtained after the removal of alternate pairs of rows and alternate triple rows (i.e. alternately three rows are cut out and the next three are left).

TABLE I. *Stocking before and after thinning*

Species (1)	*Forest, and date of planting* (2)	*Plot number* (3)	*Date of establishment as a sample plot* (4)	*Thinning grade* (5)	*Top height at 20 yrs. (feet)* (6)	*Breast height girths after 1942 thinning (inches)*		*Number of stems per acre*			*Quarter girth volume per acre (O.B.)*		
						Mean (7)	*Max.* (8)	*On Establishment of plot* (9)	*After 1942 thinning* (10)	*Percentage removed* (11)	*Total yield to 1942 (cu. ft.)* (12)	*Main crop after 1942 thinning (cu. ft.)* (13)	*Percentage removed up to 1942* (14)
Scots pine (*Pinus sylvestris* L.)	Brandon Park P.07	130	4/1939	L.C.	23½	11	21	1,620	1,130	30	927	600	35
	,, ,, ,,	131	4/1939	A	19½	12	28	1,300	1,300	Nil	853	853	Nil
	Swaffham* P.22	132	5/1939	L.C.	32	10½	19½	2,527	1,567	38	1,288	775	40
	,, * ,,	133	5/1939	A	33	12	20½	2,247	1,904	15	1,284	1,284	Nil
	,, ,,	134	4/1939	D	33½	14	20	2,297	613	73	1,275	791	38
	,, ,,	158	4/1942	D++	33	14	20	1,800	340	81	1,220	436	64
	Broomhouse P.22	156	3/1942	D	33½	13½	20½	2,146	596	72	1,465	706	52
	,, ,,	155	3/1942	D++	31½	13½	18½	2,155	355	84	1,190	368	69
	Rendlesham P.21	153	4/1942	D	31	14	22	1,652	612	63	1,134	724	36
	,, ,,	152	4/1942	D++	31½	15	24½	1,650	360	78	1,150	519	55
	Broomhouse P.25	141	5/1939	D	29½	12½	18½	1,699	710	58	755	448	41
	,, ,,	142	5/1939	A	29½	10½	19	1,693	1,643	3	599	599	Nil
	,, ,,	143	5/1939	L.C.	28½	9½	17	1,690	1,190	30	538	320	41
Corsican pine (*P. nigra* var. *calabrica* Schneid.)	Swaffham* P.24	136	5/1939	A	30½	13½	22	1,997	1,803	10	1,520	1,520	Nil
	,, * ,,	135	5/1939	L.C.	30	10½	19	1,847	1,434	22	1,390	917	34
	,, ,,	137	5/1939	D	29	15	22	2,020	600	70	1,267	694	45
	,, ,,	157	4/1942	D++	30½	15½	21	1,979	349	82	1,270	446	65
	Broomhouse P.26	139	5/1939	A	33	12½	21½	1,756	1,670	5	1,235	1,235	Nil
	,, ,,	140	5/1939	L.C.	33	12½	21½	1,623	1,243	23	1,306	880	33
	,, ,,	138	5/1939	D	34	14½	19½	1,586	600	62	1,233	666	46
	,, ,,	154	3/1942	D++	35	16	22½	1,426	336	76	1,100	471	57
	Rendlesham P.20	151	4/1942	Moderate(C)	30	15½	26	1,700	1,065	37	2,100	1,600	24
	,, ,,	150	4/1942	D	30	17	28½	1,693	608	64	1,840	1,036	44
	,, ,,	149	4/1942	D++	29½	18½	29½	1,686	366	78	2,170	899	59
	Santon Downham* P.24	162	5/1943	D	31½	15½	22½	2,212	602	73	1,738	850	51
	,, * ,,	163	5/1943	Alt. pairs of rows	32½	13½	23	2,217	1,131	49	1,841	965	48
	,, * ,,	164	5/1943	Alt. triple rows†	32	13	24	2,177	1,140	48	1,848	907	52

O.B. = over-bark. Round wood of dia. 3 in. O.B. or less, neglected.

* The data for these plots refer to 1943 instead of 1942 because they were not measured in 1942.

† Alternately 3 rows are left and the next 3 rows are cut out.

The thinning grades in the remaining eleven plots are as follows:

A	grade . .	2 plots
B	„ . .	0 „
C	„ . .	1 „
D	„ . .	3 „
D++	„ . .	3 „
L.C.	„ . .	2 „
	Total	11 plots

As in the case of Scots pine the treatments are not the same in each locality, and the plots were not all established or remeasured in the same year. Corsican pine has suffered less than Scots pine from *Fomes*, but nearly all the trees killed by this fungus are in the more heavily thinned plots.

Computation of data

All volumes and basal areas are given in quarter girth measure, over-bark, per acre. The volumes refer to timber over 3 inches diameter over-bark, smaller sized material being ignored. The corresponding under-bark volumes would be about 17 per cent. less. In order to define the density of stocking after the various grades of thinning, Mulloy's (2) 'stand density units' were first tried, but it was found that the simpler concept of basal area per acre produced almost the identical graphs, presumably because the plots are all similar in age and past history. Basal area per acre was therefore used in Figs. 1–4 as a measure of the growing stock left after thinning. Volume per acre was found unsuitable because it varies too rapidly with age; and the number of trees per acre, without considering mean girth, was equally unsatisfactory. Dr. Finney, Lecturer in the Design and Analysis of Scientific Experiment, University of Oxford, very kindly provided the statistical analysis of increment in the D grade and D++ grade plots. The data from the other plots were not suitable for statistical treatment.

RESULTS

(*a*) *Scots pine* (*Pinus sylvestris* L.)

Yield from thinnings. The various series of Scots pine plots differed considerably from one another in initial stocking and height when they were established as sample plots, as can be seen from Table I. This explains the wide range of thinning volumes obtained within any one thinning grade. In the distributive (D++) thinnings, approximately 80 per cent. of the trees and 55–65 per cent. of the original standing volume were removed, leaving some 350 stems per acre. Thinning yields were thus between 600 and 800 cu. ft. In the D grade thinnings 58–73 per cent. of the trees and 36–52 per cent. of the volume, or about 300–600 cu. ft. were removed. In the L.C. grade plots 30–38 per cent. of the trees were cut out, but as these were mainly dominants and co-dominants that were interfering with better dominants, thinnings amounted to as much as 35–40 per cent. of the standing volume, or 200–500 cu. ft., not markedly less than in the D grade. It is unfortunate that not a single plot was thinned to a C grade which would have

approximated more closely to divisional practice. The three A grade plots produced no measurable thinning volume at all.

Periodic annual increment (Figs. 1 and 2 and Table II). In Fig. 1 the periodic

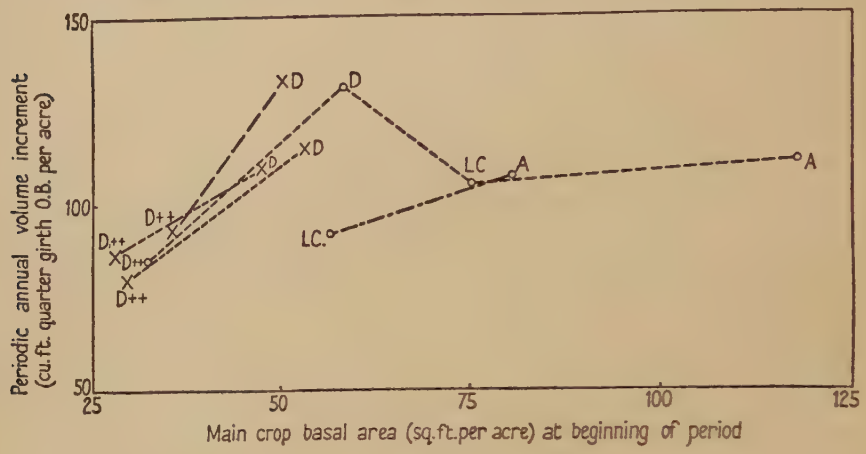

Fig. 1

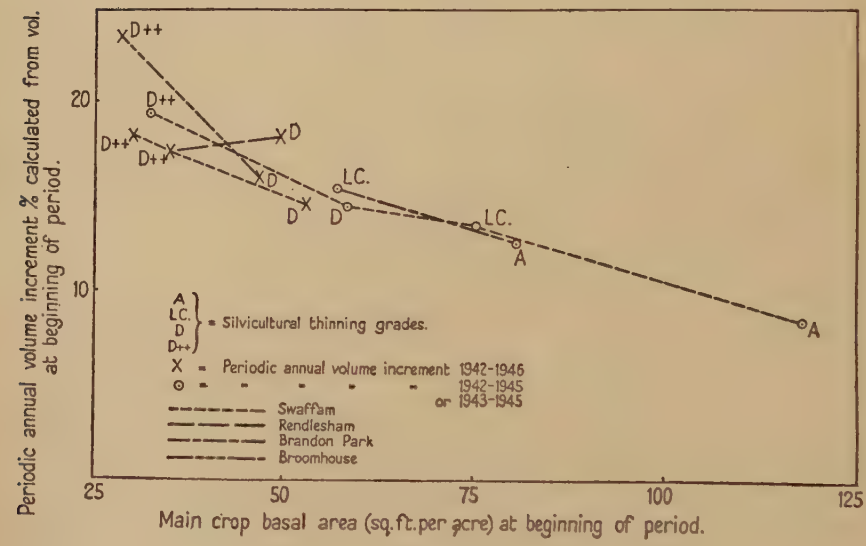

Fig. 2

annual increments have been plotted over the main crop basal area after thinning. Heavy thinnings leave small basal areas and light thinnings leave large ones, as is clearly indicated by the distribution of the points in relation to the horizontal axis of the graph. Points derived from the same locality and the same period, i.e. points which are strictly comparable, have been connected by dotted lines, the type of dot indicating the actual locality as given in the legend to Fig. 2; but

owing to the paucity of data no attempt has been made at fitting smooth curves. The figure shows that D grade thinnings have clearly produced more increment than the D++ grade thinnings. The treatment means are 122±6 cu. ft. per acre per annum for the D grade, and 88±6 cu. ft. for the D++ grade. The difference is thus highly significant, statistically.

TABLE II. *Summary of the periodic annual increments and their standard errors in the D grade and D++ grade plots at Rendlesham, Swaffham, and Broomhouse (1942–6).*

Basal Area (sq. ft., quarter girth, per acre)			
	Scots pine (Pinus sylvestris L.)	*Corsican pine (P. nigra* var. *calabrica* Schneid.)	*Mean*
D	5·13 (±0·25)	7·09	6·11 (±0·18)
D++	4·05	5·91	4·98
Mean (±0·18)	4·59	6·50	5·54
Swaffham	4·77	6·90	5·84 (±0·21)
Broomhouse	4·41 (±0·31)	6·60	5·50
Rendlesham	4·59	6·00	5·30
Volumes (cubic feet, quarter girth, over-bark, per acre)			
	Scots pine	*Corsican pine*	*Mean*
D	122·0 (±6·0)	168·7	145·4 (±4·3)
D++	88·2	138·2	113·2
Mean (±4·3)	105·1	153·4	129·3
Swaffham	99·9	145·8	122·9 (±5·2)
Broomhouse	101·3 (±7·4)	141·3	121·3
Rendlesham	114·2	173·2	143·7

The few points for L.C. grade and A grade plots are inconclusive. At both Brandon Park and Swaffham the A grade plots grew slightly faster than the L.C. grade plots; and at Swaffham the L.C. grade plot put on less increment than the D grade plot; but these differences are small compared with the errors of estimating increment over such short periods, and in the absence of adequate replication obviously insignificant. The position of the D grade plots in relation to the D++ grade plots does suggest that the maximum increment would be obtained by a growing stock larger than that left after a D grade thinning. In other parts of the country, on the other hand, B and D grade thinnings have produced almost identical increments in series of Scots pine plots which have been under observation for over 20 years; and some of them are now 60 years old.

Some of the plots were remeasured every year for 4 years, between 1942 and 1946. It was found that increment fluctuated considerably from year to year, increments generally being lowest in the first year after thinning and highest in the second or third year. The largest fluctuations occurred in the D++ plot

at Broomhouse, where the increment was 108 cu. ft. in the first year and 196 cu. ft. in the third year after thinning. The fluctuations in the other plots were slightly less but without exception exceeded 30 cu. ft. Volume increments over such short periods cannot be determined accurately, but similar large fluctuations approaching significance level at 5 per cent. probability were found in the basal area increments, the determination of which is subject to very small errors only. It is not possible, however, to say to what extent these differences in annual increment reflect the time it takes Scots pine to make full use of the increased growing space after thinning, and to what extent they merely are due to fluctuations in growth which are caused by the weather.

In Fig. 2 periodic mean annual increment expressed as a percentage of the initial main crop volume after thinning is plotted over the initial main crop basal area. It is evident from this figure that increment per cent.—in contrast to actual increment—varies inversely with the growing stock; and within the range of values encountered the relationship between increment per cent. and initial main crop basal area appears to be linear.

The fact that increment per cent. after D++ grade thinnings is higher than after D grade thinnings suggests that there must still be considerable competition between trees after a D grade thinning, but this must be mainly root competition, because crown competition is almost entirely eliminated by a D grade thinning.

(*b*) *Corsican pine* (*Pinus nigra* var. *calabrica* Schneid.)

Yield from thinnings. The Corsican pine plots at Broomhouse and Swaffham were 16–18 years old and the Rendlesham plots 22 years old in 1942. This is why the total yield up to that year was low in the first two localities, with 1,100–1,300 cu. ft. per acre, compared with the 1,840–2,170 cu. ft. per acre in the Rendlesham plots. Thinning yields were also correspondingly higher at Rendlesham. The D++ grade plots produced 600–800 cu. ft. in the first two localities, and 1,270 cu. ft. at Rendlesham; for the D grade plots the corresponding figures were 570 cu. ft. and 800 cu. ft. The L.C. grade plot at Broomhouse produced 430 cu. ft., and the one at Swaffham 470 cu. ft. The only C grade plot which was at Rendlesham produced 500 cu. ft. In both Scots pine and Corsican pine the greater part of the thinning yields were obviously pitwood, but there is no record of the amount that was unfit for the purpose and had to be classed as firewood.

Periodic annual increment (Figs. 3 and 4 and Table II). In Fig. 3 periodic annual volume increments have been plotted over initial main crop basal area in the same way as was done for Scots pine in Fig. 1, and strictly comparable points are connected by interrupted lines, the pattern of dots and dashes indicating the locality. The points for Santon Downham, however, are not connected, because in these three plots a silvicultural D grade thinning is contrasted with the mechanical removal of whole rows of trees. Differences in increment between these three plots are therefore primarily due to the type and not the severity of the thinning.

Fig. 3 suggests that there is a fairly close relationship between volume increment and main crop basal area after thinnings. The superiority in increment of the D grade plots over the D++ grade plots is highly significant statistically, the

means being 169±6 cu. ft. and 138±6 cu. ft. per acre per annum respectively. These increments are 30 to 50 per cent. higher than the corresponding increments for Scots pine. The more lightly thinned Corsican pine plots were not suitable for statistical treatment, but the graph suggests that there is only a slight increase in volume increment if the main crop basal area is more than 75 sq. ft. per acre. At Swaffham the A grade plot has in fact produced very much less increment than either the D grade or the L.C. grade plots, but the increment figures for this A grade plot are unreliable because the size of the plot was reduced from 0·3 acre to 0·233 acre in 1942 when a ride was cut through the plantation.

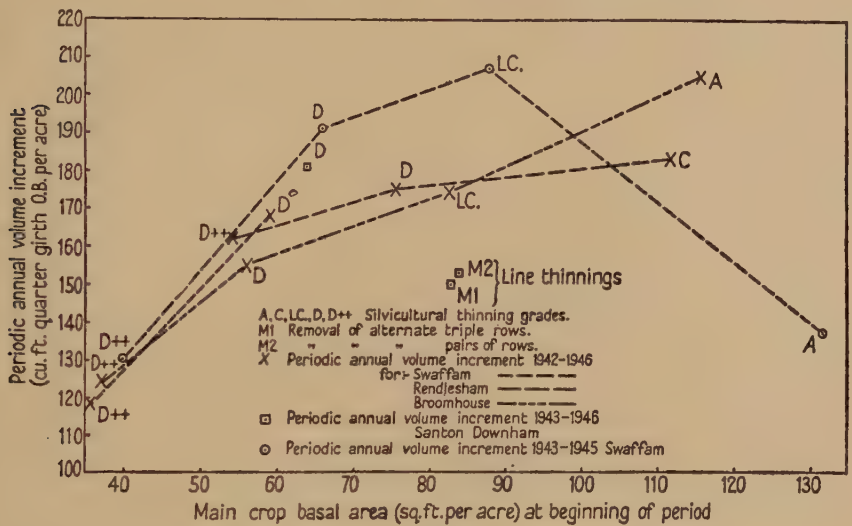
Periodic annual volume increment (cu. ft. quarter girth O.B. per acre)
Main crop basal area (sq. ft. per acre) at beginning of period
A, C, LC., D, D++ Silvicultural thinning grades.
M1 Removal of alternate triple rows.
M2 " " pairs of rows.
X Periodic annual volume increment 1942-1946 for:- Swaffam
Rendlesham
Broomhouse
Periodic annual volume increment 1943-1946 Santon Downham
Periodic annual volume increment 1943-1945 Swaffam
M2 M1 Line thinnings

Fig. 3

As in the case of Scots pine it was found that increment fluctuated considerably from year to year and that it was usually lowest in the first and highest in the third year after thinnings. These differences approached significance level at 5 per cent. probability and may be due either to a delayed response to thinnings or merely to fluctuations in the weather from year to year. Fig. 3 shows that at Santon Downham the D grade plot has produced an increment similar to that obtained elsewhere with the same thinning grade, but the two plots in which alternate pairs of rows and alternate triple rows of trees were removed have put on much less increment, although their initial main crop basal area after thinning was somewhat larger. This strongly suggests that silvicultural thinnings produce more increment than the mechanical removal of whole rows of trees. This is what one would expect, but in the absence of any replications it would not be safe to draw definite conclusions.

The D grade plot differed from the mechanically thinned plots not only in the rate of growth but also in the composition of the growing stock that was left after thinning. Before thinning, all three plots were similar in every respect. After thinning, the growing stock in the mechanically thinned plots consisted of

approximately 1,100 trees with a mean girth of 13–13½ inches, while in the D grade plot only 600 trees were left, but they had a mean girth of 15½ inches, so that the main crop volume and basal area in the D grade plot was not appreciably less than in the other two. This difference in the composition of the growing stock is explained by the fact that in D grade thinnings it is mainly the small and medium-sized trees that are removed, while in the thinning of whole rows the trees are cut out irrespective of size. The thinning data do not give the quality of tree removed, but as Flentje and Gough (1) have pointed out, if 50 per cent. of the crop is removed mechanically by cutting out whole rows, the chances are that 50 per cent. of the best trees and 50 per cent. of the worst trees will be cut out. In silvicultural thinnings, on the other hand, nearly all the best trees are left, and bad and indifferent trees only are removed.

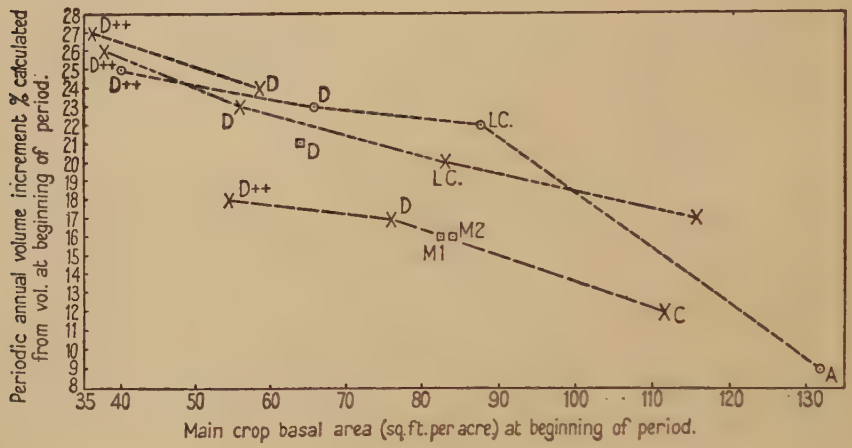

Fig. 4

Fig. 4 shows that, as in Scots pine, increment per cent., in contrast to actual increment, varies inversely with main crop basal area; and the relationship between the two factors is approximately linear throughout the range of basal areas encountered. The increment percentages in the Rendlesham plots are lower than those at Swaffham and Broomhouse, probably because of their greater age and larger sized trees.

DISCUSSION

To what extent do these results to date answer the questions which were posed in the introduction?

Periodic annual increment in Scots pine has varied between 80 and 130 cu. ft. per acre per annum, and the extreme figures for any one year were 50 and 196 cu. ft. Nearly all the plots which averaged less than 100 cu. ft. were D++ grade plots, a thinning grade which is not normally employed. The average annual rate of growth may be taken, therefore, as about 100–120 cu. ft. over-bark, or 80–100 cu. ft under-bark at an age of 18 to 24 years.

For Corsican pine the figures are somewhat higher, the periodic annual increments ranging between 116 and 206 cu. ft., with an absolute maximum and minimum for any one year of 63 and 289 cu. ft. Ignoring the D++ plots, increments are mostly between 150 and 200 cu. ft. per acre over-bark or 120 to 160 cu. ft. under-bark. All these figures apply to the fully stocked sample plots, and they could only be applied to whole plantations by making an allowance for stocking and for differences in site quality. It is likely that the sample plots are slightly above average in this respect.

The results to date provide no definite answer to the second and third questions: 'What thinning grade produces the maximum increment?' and 'Do crown thinnings produce more or less increment than equally severe low thinnings?' The increment figures, however, do suggest that in order to obtain the maximum increment, thinnings must not be more severe than a D grade, at this stage, and probably less severe.

The D++ grade plots provide a partial answer to the fourth question: 'What is the heaviest thinning that can be carried out while still leaving a useful main crop?' All the D++ grade plots in both species of pine, with their main crops of 300–350 trees per acre, have produced between two-thirds and three-quarters of the increment of the D grade plots with 600 stems per acre. Clearly the very heavy thinnings have produced no immediate check in growth; and although such very drastic thinnings are probably undesirable silviculturally, they appear to be preferable to large-scale clear fellings in an emergency such as the war of 1939–45.

The three plots at Santon Downham suggest that the mechanical removal of alternate pairs of rows and alternate triple rows produces less increment than silvicultural thinnings of equal severity, a result which is to be expected.

The final question: 'How much is the yield from thinnings likely to be under various thinning grades?' can only be answered in respect of the early thinnings, which are covered by the data, and even there only very tentatively. The average volumes per acre removed in the first main thinnings were as follows:

	Scots pine		*Corsican pine*	
Thinning grade	*No. plots*	*Yield cu. ft.* per acre*	*No. plots*	*Yield cu. ft.* per acre*
A	3	Nil	2	Nil
B	0	No data	0	No data
C	0	No data	1	500
D	4	490	4	700
D++	3	750	3	910
L.C.	3	350	2	450
Alt. pairs rows	0	No data	1	875
Alt. triple rows	0	No data	1	940

* Quarter girth measure, over-bark, neglecting 3-in. dia. O.B. or less.

These first real thinnings are usually carried out when the crop is between 18 and 22 years old. What is cut out then may be considered to be the total thinning yield up to 20 years of age.

Present divisional practice would probably correspond most closely to a C grade, i.e. a moderate low thinning; and the only C grade plot was in fact thinned by divisional staff. The volume of produce from subsequent thinnings, between the ages of 20 and 40 years, can only be inferred from the proportion of the annual increment that is likely to be removed. For Scots pine this increment was estimated at 100–120 cu. ft. O.B., and for Corsican pine at 150–200 cu. ft. O.B. per acre per annum. Yield tables indicate that the rate of growth does not change much between 20 and 40 years, although it may diminish slightly with age; and the present data suggest that increment does not vary greatly with thinning grade, unless thinnings are heavier than a D grade.

Light thinnings (B grade) may be expected to remove about one-quarter, moderate thinnings (C and L.C. grades) about one-third, and heavy thinnings (D grade) about one-half of the annual increment. On this basis average annual thinning yields for the two species between 20 and 40 years are estimated to be as follows, provided that thinnings are carried out at reasonably frequent intervals of 3–6 years:

Thinning yields in cu. ft. per acre per annum

(Quarter girth measure, over-bark, neglecting 3-in. dia. O.B. or less.)

Type of thinning	*Scots pine*	*Corsican pine*
B grade	25–30 cu. ft.	35–50 cu. ft.
C „	30–40 „	50–70 „
D „	50–60 „	75–100 „
L.C.	30–40 „	50–75 „

The equivalent under-bark figures would again be 17 per cent. less.

These very scanty data for first thinning volumes from our permanent sample plots have recently been augmented by data from a considerable number of temporary $\frac{1}{10}$ acre circular plots which were established by Messrs. Conder, McKay, and Gough, District Officers of the Forestry Commission, who have very kindly permitted me to quote from their results. Their volume figures are not directly comparable with the others given in this paper, because their measurements extend to a diameter limit of $1\frac{1}{2}$ inches instead of 3 inches. In 1947 about 100 $\frac{1}{10}$ acre plots were measured, having been thinned according to local standard practice (approximately a C grade). In addition the actual thinning yields were recorded from several whole compartments, totalling about 200 acres of each of the two species of pine. The overall average thinning yields worked out at about 40 cu. ft. per acre per annum for Scots pine, and about 50 cu. ft. for Corsican pine. Starting from an age of 12 years, the actual amount removed in any one thinning depended on the number of years over 12, in the case of first thinnings, and on the number of years since the previous thinning in the case of subsequent thinnings. Nearly all the stands investigated were under 30 years of age. In 1948 Gough measured 140

$\frac{1}{10}$-acre plots in first thinnings of Scots pine. In these plots the average thinning volume per acre was 265 cu. ft., or 27 cu. ft. for every year over 12. He also measured 90 $\frac{1}{10}$-acre plots in first thinnings of Corsican pine, and in these the average thinning volume per acre was 445 cu. ft., or 51 cu. ft. for every year over 12.

CONCLUSIONS

The data hitherto obtained are obviously inadequate for drawing any definite conclusions, but so far as they go they suggest that in considering what thinning policy should be adopted, the following are the main points to be borne in mind:

1. If maximum volume production is the primary aim, thinnings should certainly not be heavier than a D grade, and probably somewhat lighter. If, on the other hand, production of large-size timber in the shortest possible time is the primary object, then thinnings should certainly not be lighter than a D grade and probably somewhat heavier, though this will entail a definite loss of increment.
2. If it is anticipated that casualties from *Fomes* will be as heavy as or heavier than they have been in the past, a fairly conservative thinning policy is indicated, to ensure that casualties do not create too many large gaps in the canopy that will not close within a reasonable period.

SUMMARY

1. Thirteen Scots pine (*Pinus sylvestris* L.) and fourteen Corsican pine (*Pinus nigra* var. *calabrica* Schneid.) plots were established in East Anglia between 1938 and 1943 in 18–25-year-old plantations, in order to determine the effect of different thinning treatments on increment, thinning yields, and general development of the stand.

2. Periodic annual increment has averaged 150–200 cu. ft., quarter girth, over-bark, per acre, per annum, in Corsican pine; and 100–120 cu. ft. in Scots pine. The under-bark figures are about 17 per cent. less.

3. Thinnings between the ranges of B and D grades do not seem to affect volume increment appreciably, but thinnings heavier than a D grade cause a definite loss in increment.

4. Very heavy thinnings (D++) have caused a loss in increment per acre but have not produced a check in the rate of growth of the surviving trees.

5. There is some evidence that heavy thinnings increase liability to attacks from *Fomes annosus* Fr.

6. The present moderate thinning policy in East Anglia appears to produce average thinning yields of about 30 to 40 cu. ft. quarter girth, over-bark, per acre, per annum, for Scots pine, and about 50 cu. ft. for Corsican pine, starting at an age of about 12 years.

LITERATURE REFERENCES

(1) Flentje, W. M., and Gough, P. C.: 'The Application of Line Thinning to the Forests of East Anglia.' *Emp. For. Rev.* 25, No. 2, 1946.

(2) Mulloy, G. A.: *Stand Density Units*, Silv. Leafl. No. 16. Dept. of Mines and Resources, Lands, Parks, and Forests Branch, Canada.

(3) Rishbeth, J.: '*Fomes annosus* Fr. on Pines in East Anglia.' *Forestry*, xxii. 2, 174, 1948.

THE SOIL CONDITIONS WHICH DETERMINE WIND-THROW IN FORESTS

By W. R. DAY

(*Department of Forestry, University of Oxford*)

IT is now thirty years since the First World War ended. The plantations which were then begun, both in private and State woodlands, have already received or will soon receive their first thinnings. One of the considerations which must often be in a forester's mind at such a time is whether or not the crop is susceptible to wind-throw, and if so, how it is to be avoided. Wind-throw is one of the common incidents in the forest, and the general circumstances in which it is liable to be serious are probably well known to all foresters of experience; but it is perhaps worth while discussing some of the conditions, and especially soil conditions as affecting root development, which help to determine the possibility of extensive overthrow.

Experience in Britain seems to show quite clearly that the overturning of trees by strong winds is nearly always made possible by unsafe anchorage, and is not ordinarily caused by the tearing up of a well-rooted tree. Safety in anchorage is a mechanical matter and is determined by the inertia which the mass of soil gripped by the root opposes to the force applied to the crown of the tree. If the soil mass is sufficiently great and is held sufficiently firmly, the tree may break but it will not be uprooted. Thus it is to be expected that wind-throw will become a serious problem on soils which permit only of shallow rooting; and in Britain the greater part of the soils available to forestry are of this type. While this does not mean that all our forests will be seriously menaced by wind-throw, it does imply that it will be a serious problem on the shallower soils in those places which are the more exposed to strong winds. It is essential to be able to recognize, therefore, what it is that produces the mechanical instability of trees and so their liability to overthrow.

There are certain conditions which are quite obvious in this connexion. It is possible, in regions of high rainfall and especially in low situations which receive considerable drainage topographically, to grow quite tall trees where the soil is shallow, often only a few inches in depth and overlying impenetrable rock. Sudden storms are very liable to blow down such trees, and there is very little that can be done to prevent it, except to maintain any shelter which may be given by more firmly rooted surrounding trees. These sites usually cover no great area and are of no appreciable economic importance.

There are times, however, when even fairly deeply rooted trees are overthrown. Such an occasion occurred on the sudden melting of the snow in the late winter in 1947. As a result an immense amount of water was produced within a short period. Where the basal layers of soils were characterized by impedance in drainage

and particularly where the slope of the ground was gentle, so that topographical drainage was poor, this large volume of water drained away slowly. On such sites the result was that the lower part of the root systems, even where rooting was moderately deep, lay in soil which was entirely saturated with water. Examination immediately after wind-throw in Bagley Wood, near Oxford, of trees thrown by the gales which occurred at the end of March 1947 showed that the lower layers of soil, in their water-saturated condition, had become so soft that they were semi-liquid and offered no secure anchorage to the trees. European and Japanese larch (*Larix decidua* Mill. and *L. leptolepis* Gord.), Douglas fir (*Pseudotsuga taxifolia* Brit.), and Corsican pine (*Pinus nigra* var. *calabrica* Schneid.), as well as Norway and Sitka spruce (*Picea abies* Karst and *P. sitchensis* Carr.), all blew over under these conditions. The root-system in many cases was more than 4 feet deep and mostly or entirely healthy. It is to be noted that in this wood, on soils which drain freely and encourage deep rooting, Norway spruce with sound unrotted stems broke off but did not overturn.

The importance of these observations is that they suggest that liability to wind-throw is increased whenever the rate of subsoil drainage is so slow that after long continued rainfall or sudden melting of deep snow the roots are no longer able to hold together the water-saturated layers of soil. The basal mass, which ordinarily counterbalances wind-pressure on the crown, is then much reduced and, moreover, is set on a soft water-lubricated and easily movable foundation. It should be noted that it is possible for these conditions to arise without the root being diseased.

One comes now to the relationship between root disease and wind-throw. It is a characteristic of many of the soils available for forestry in Britain that sooner or later, according to the soil type and the species of tree, root disease arises. The most frequently seen evidence of this is butt-rot. Its development depends, fundamentally, not merely on the presence of a particular fungus flora in the soil but on the existence also of physical conditions which, at least intermittently, become pathogenic. Such root disease reduces or restricts the mass of soil held together by the roots, and so promotes liability to overthrow.

Wind-throw is not ordinarily of importance on soils which are freely draining and permit of deep rooting, but it does occur. Beech which stand on shallow soil over hard fissured chalk sometimes provide an example. Examination of any such beech which have been wind-thrown shows that they have developed a shallow and usually extensive root-plate within the equally shallow depth of soil overlying the chalk rock. It will also be found that from this root-plate there was a development of roots in the fissures in the rock. These fissure-roots may go down for 5 or 6 feet, at least, and plainly they help very largely to anchor the tree safely. They are, however, liable to die; and the main causes of death seem clearly to be lack of water, together with, where it exists, starvation caused by lime-induced deficiency. A dead root has, of course, little mechanical strength, and thus the overturn of the tree is facilitated. In such a case, therefore, the tree may appear, superficially, to be shallow rooted but actually be deep rooted; and its liability to overthrow is largely determined by the death of the deeper roots. The importance of this example lies not in the species, for beech is usually fairly wind-firm, but in

the light it throws on the influence of physical or chemical factors, which act pathogenically to cause the death of roots and so make the tree mechanically unstable in high winds.

Wind-throw will tend to occur on any other type of freely draining soil, however deeply rooted the trees may be, if at times there is extensive dying back of the deeper roots. The really serious chances of extensive wind-throw seem to be associated, however, not with any of the types of freely draining soil but with more or less shallow soils in which shallowness of rooting is determined by poor drainage. This case is really fairly simple. Its essential feature is that a zone occurs, often within less than 24 inches of the soil surface, within which roots cannot live permanently, even though they may enter. It can be demonstrated that under these conditions the development of root disease is inevitable. This disease first of all takes the form of the dying of the root-fibres upon which the feeding rootlets develop; as conditions become increasingly adverse, with the growth of the tree, larger roots are affected and die. The development of root parasites is favoured by the debility which arises after this manner, and, especially as the larger roots are affected, butt-rot is always liable to appear.

Now there are certain important characteristics of soils of this type, in so far as liability to wind-throw is concerned:

(*a*) Usually the adverse substratum of soil can be improved only to a very limited extent, at the most, and has to be accepted as a permanent characteristic. The main thing one can do is to alleviate, as far as possible, the conditions which develop as a consequence of the soil's fundamental character.

(*b*) This character implies certain things, physically:

i. The adverse layer will hold up water so that at times that layer and also the drainable soil immediately overlying it will become saturated. Conditions of greatest lubrication for the mechanical movement of the entire root system then obtain.

ii. Not only will oxygen supply be unduly low, in so far as the restricted rooting space becomes waterlogged, but in dry years there may be a deficiency of water. It thus happens not uncommonly that the root system suffers injury from extremes both of dryness and wetness.

iii. A condition of inherent mechanical instability will arise when the rooting layer is really shallow.

The restricted rooting space, the pathogenic conditions which tend to prevail within it, and the inherent tendency for the trees to be mechanically unstable in high winds all seem to imply that in practice two things should be attempted. Firstly, the drainage of free water from the limited rooting space should be facilitated as far as possible. This will tend to reduce the lubrication of the movement of the root-mass and also to reduce the extent to which disease develops within it. Secondly, the centre of gravity of individual trees, or of masses of trees, should be kept as low above the ground as possible, so that the moment of the force acting on the crown or group of crowns shall also be kept as low as possible, relative to that of the counter-balancing root-mass.

The conversion of these two things into rules for everyday practice in forestry is not so simple as it might seem. It is very doubtful whether the physics of drainage under varying topographical and soil conditions have been adequately studied, so that one may estimate with adequate accuracy the effect of the ditch draining that is, usually, all that is possible in forestry. Equally little is known of the efficiency of different species of tree in maintaining naturally the drainage of the rootable soil, and so promoting the relative stability of the forest. There seems to be ample ground for both short-term reconnaissance and long-term investigation here.

The second point (low centre of gravity) concerns thinning practice and the distribution of age classes over the area. The argument implies that deep crowns are preferable to shallow crowns, and that the grouping of the canopy of the forest into irregular masses is preferable to the maintenance of a canopy that is relatively even, both in height and age. Appropriate thinning practice should be within present control; but the development of an irregular, uneven-aged forest from one that is even-aged will inevitably take time and cannot be planned according to any rigid system.

It is perhaps of interest to note that the possibility of serious wind-throw arises as one of a group of problems. All of them derive from the raising of a forest on soils which, considering the growth potentialities of the species of tree used, are unduly limited in rooting capacity, or become so intermittently, according as weather conditions change periodically. The case of the root disease which precedes butt-rot has already been mentioned; the rot comes in merely as a particular aspect of a diseased condition which in certain circumstances also facilitates wind-throw. It is clear, too, that the dying of patches of trees, in plantations which are usually in the high pole stage, is often merely another aspect of this root disease, which inevitably arises on soils of unduly limited capacity. The splitting of the main stems of conifers during 1947, which will have come to the notice of many foresters and is to be attributed to drought, is yet another aspect of disease which is related to this same soil limitation. It is important to realize that phenomena outwardly as different as these may all be traced back to certain fundamental types of limitation in soil conditions, the particular phenomenon which arises depending on the associated factors acting in conjunction with the fundamental edaphic limitations.

Many foresters will have experience of shallow soils of the general type referred to here, in which poor drainage exists in the subsoil, for most of the forest land in Britain is included within this type. The more important particular types, in so far as wind-throw is concerned, are probably to be found in the moorland and hill districts of the west and north. Land dominated by *Molinia caerulea* Moench. together with, in varying proportions, other plants such as ling (*Calluna vulgaris* Brit.), the bell heathers (*Erica cinerea* L. and *E. tetralix* L.) and bog asphodel (*Narthecium ossifragum* Huds.), and moorland with but a shallow depth of well-drained soil and bearing poor ling, together with varying proportions of other plants such as deer grass (*Scirpus* spp.), the mat grass (*Nardus stricta* L.), bilberry (*Vaccinium myrtillus* L.), and bog cotton (*Eriophorum* spp.), probably provide the

most extensive areas on which large-scale, serious wind-throw may occur, if trees are raised. But there are many areas where only shallow rooting is possible, as on soils derived from some of the clayey gravels, fine silty sands, clays, shales, and slates, on which any exceptional wind may cause serious overthrow, especially if the forest exists in the form of tall, dense, under-thinned plantations. The modern extensive use of spruce (*Picea* spp.) in forestry in Great Britain is probably justified from a utilization standpoint; but it does raise the danger of overthrow by strong winds, and demands that special consideration shall be given to this in appropriate circumstances. There are several reasons why the use of spruce raises this issue. The spruces, though they are not necessarily shallow-rooted trees, tend under conditions of impeded drainage to be more shallow rooted than at least some other species; also they withstand mutual competition better than most other species and so make delay in thinning appear to be less serious. Because of these things, stands of small-crowned trees with small shallow root-systems may be raised, trees, in fact, which are just in the condition to favour wind-throw. It has to be remembered, however, that any species of tree reacts to similar treatment in more or less the same way. It is inevitable that as extensive forests develop, problems such as that discussed here will arise. All that matters is that there shall be an adequate attempt to understand them.

The literature on wind-throw in forests is very extensive and it is not proposed to discuss it here. The mechanics of the problem, in so far as the individual tree is concerned, are discussed exhaustively by Fritzsche (1), to whom those interested may refer. He lays great stress on the importance of the large, more or less horizontally running, roots as struts which support the tree during storms. It is, of course, quite correct that they have this function; but it should be remembered also that the proper functioning of such roots as struts depends on their having a secure foundation. Their foundation is provided by the root-mass which is appended to them, and consists of soil interwoven with and held together by the general root-system of the tree. Heart-roots or tap-roots, which are independent of these large horizontal runners, act as part of the general foundation. The examination of wind-thrown trees which stood on stony soil shows commonly the presence of descending anchor roots, the ends of which have been scoured by rubbing on stones. This scouring is clear evidence that the trees were rocking on their foundation before being overthrown. The presence of the horizontal 'strut roots' is unable to prevent this rocking which follows inevitably on the death of the ends of the deeper-going 'anchor roots'. Rocking of the root-system occurs on stoneless soils, though there, of course, scouring is absent. It may be experienced not uncommonly when one is in the forest on a windy day, in a suitable locality. It is evidence that the trees have become prepared, mechanically, to be overthrown when a really high wind strikes them. The important anchor roots include the mass of fine roots in the lower part of the root-system as well as any of the larger roots which happen to descend. It is this mass of fine roots which so commonly dies as the result of impedance in drainage in the subsoil, and by its death destroys the fixity of the foundation of the tree, and so prepares the way for wind-throw.

This argument leads inevitably to the conclusion that, given an equal degree of exposure and a comparable type of tree, wind-throw will tend to occur more frequently in those places in which soil conditions prevent the development or maintenance of adequate fixity of the root-mass. A survey of an area susceptible to wind-throw should reveal where such places are and make it possible for them to receive special treatment. The importance of this lies in the experience that extensive wind-throws often develop as the result of an initial breakdown in such susceptible areas.

Very interesting discussions on meteorological and topographical conditions in relation to wind-throw will be found in papers by Woelfle (2, 3), who also discusses the importance of the shape and structure of the canopy in this connexion. It is outside the scope of this article to discuss these matters, the aim here being to direct attention to the relation between soil conditions, the fixity and health of the root-system and wind-throw.

SUMMARY

The effect of soil conditions on root development and anchorage against wind-throw in Britain is examined briefly, with reference to recent original observations in that country and work by others in central Europe. The crux is held to be the gripping of an adequate inert mass of soil by the roots. The importance of drainage is brought out, and the danger when exceptional weather makes the critical layers of a soil semi-liquid and unstable. No root disease may be associated with overturning in such conditions. On the other hand beech on shallow soil over chalk may be wind-thrown through starvation and death of roots running down five or six feet into the fissured chalk rock. The physics of ditch draining require study, and so does the ability of various tree species to maintain natural drainage. Where there is special danger of wind-throw it is held that thinning practice should favour deep crowns rather than shallow, and the silviculture should favour an irregular rather than an even canopy.

Particular types of soil and vegetation in Britain where the danger of wind-throw is high are mentioned, with special reference to spruce (*Picea* spp.).

LITERATURE REFERENCES

(1) Fritzsche, Kurt: 'Sturmgefahr und Anpassung.' *Thar. Forstl. Jahrb.* lxxxiv, 1933, 1–94.
(2) Woelfle, Max: 'Wald und Windschutz.' *Forstw. Centralbl.* lvii. 1935, 349–362.
(3) —— 'Sturmschäden im Wald.' *Forstwiss. Centralbl.* lviii, 1936, 605–617 and lix, 1937, 77–92 and 565–88.

AN EXAMPLE OF PERIODIC VARIATION IN FOREST SAMPLING

By D. J. FINNEY

(*Lecturer in the Design and Analysis of Scientific Experiment, University of Oxford*)

INTRODUCTION

IN a recent paper [1948 (2)] the relative merits of random and systematic strip sampling of forests for the estimation of timber volumes have been discussed. No purely theoretical reasons for always preferring one system of sampling can be adduced. The choice of a sampling scheme must depend on accumulated experience of the variation normally encountered in forests, as well as upon the particular circumstances of the investigation in progress. The precision of an estimate based upon a systematic sample cannot be assessed from the sample itself, except possibly by the addition of some supplementary sampling, though that precision will often be greater than for a random sample at the same intensity. These two factors, knowledge of the precision and securing maximum precision, must be considered before the choice is made.

Information on the gain in precision to be expected in systematic sampling is clearly important, and can only be obtained empirically. In the previous paper tentative conclusions were based upon detailed analyses of two areas (Mount Stuart in south India and Blacks Mountain in California), but it was recognized that far more evidence must be examined before any trustworthy estimate of the average gain could be made. To this end further sets of data from extensive forest enumerations are being analysed. One of these (Dehra Dun in north India) shows interesting features which did not occur in the earlier analyses, since it has a marked regular periodic component of variation. As was pointed out earlier [1947 (1)], such periodicity is very disturbing to the precision of systematic sampling: a general gain in precision for systematic sampling as compared with random may disappear, or even be converted into a loss, at certain sampling intensities. The purpose of this paper is to describe the results of a statistical analysis of sampling problems for these Dehra Dun data analogous to those of the previous paper: the terminology and methods have already been fully described [1947 (1), 1948 (2)], except for complications introduced by the periodicity.

THE DATA

Griffith [1947 (3)] has reported the enumeration of the sal (*Shorea robusta* Gaertn.) forests of the Dehra Dun Division of the United Provinces, northern India. The climate and floristics of this northern tropical moist deciduous forest are summarized in his paper. In 1947 a 20 per cent. enumeration of this area was made, using strips of 2 chains in width but enumerating only every fifth strip of the total number that could have been taken. The trees in each 5-chain length

of strip were recorded separately, so giving recording units of 1 acre. Sahai [1947 (4)] has given a detailed account of the enumeration procedure. For the two chief species, *Shorea robusta* Gaertn. and *Terminalia tomentosa* W. et Arn, records were kept of the number of trees in 4-inch diameter classes from 12 inches to 24 inches, and over 24 inches. These were converted to volumes, by local volume tables. By the kindness of Dr. Griffith the total volumes for the two species, in each recording unit, have been made available to the writer.

The data used in this paper relate to 292 strips, containing 8,506 recording units. At the north-western end of the base line the strips were short, mostly containing only 5–15 units; almost all of strips 42–171 had 30–50 units and none less than 20; strips 176–192 were short (188 had only 2 units); and with the exception of the short strips 279–282 the remainder were almost all between 25 and 45 units long. As in the previous paper [1948 (2)], only the one-dimensional sampling problem has been considered, the mean volume of timber per strip being used for analysis, without any attempt to make allowance for differences in strip length.

THE ESTIMATES OF VARIANCES

For the Mount Stuart and Blacks Mountain forests examined previously, data from complete enumerations of all strips in the areas were available. For Dehra Dun the 292 strips are themselves only a 20 per cent. systematic sample from a complete series of 1,460 strips that might have been enumerated. Hence no comparisons can be made with the true mean volume for the forest. Instead, samples of less than 20 per cent. may be compared with the 20 per cent. results. In other words the 292 strips may be used as though they constituted a complete enumeration of some forest, and different schemes of sampling from them may be compared. The analysis may not give an entirely fair picture of the relative merits of random and systematic selection of samples from the whole forest, for these are largely dependent upon the correlations between adjacent and near-adjacent strips: the samples to be discussed will not be all possible samples of a particular type that might be drawn from the forest but only the restricted set contained within the 292 strips, and correlations between successive strips of the 292 will in general be lower than between adjacent strips.

If suitable records for analysis were plentiful, the Dehra Dun series might have been discarded because of the limitation to sub-sampling from a 20 per cent. sample. In fact, records that may be used in extensive studies of sampling variation are too few for any to be lightly put on one side. The Dehra Dun records have therefore been analysed, in the first instance exactly as described for the other two forests. For convenience in terminology, the sampling will be described as though the 292 strips were the whole of a forest, so that what is termed a sample of 1 in r is in reality a sample of 1 in $5r$ from the true forest of 1,460 strips but constrained to be selected only from the particular set of 292 strips enumerated.

The volume of timber averaged 1,028·4 cu. ft. per acre for the 292 strips (unweighted average of strip means). At the north-western end of the forest the volumes were greater, most strips having more than 1,500 cu. ft. per acre, and some over 2,000 cu. ft. per acre; at the south-eastern end values fell to about

500 cu. ft. per acre. The variation was very great and erratic, the extremes being 2,900 cu. ft. and 120 cu. ft. per acre.

For unrestricted random sampling, calculation from the sum of squares of deviations of the 292 strips gives

$$s_{\mathrm{I}}^2 = 207{,}400$$

in units of (cu. ft. per acre)^2. Table I shows estimates of variance per strip for stratified random sampling in blocks of $2r(s_{\mathrm{II}}^2)$, stratified random sampling in blocks of $r(s_{\mathrm{III}}^2)$ and systematic sampling (s_{IV}^2). For random sampling, calculations were made for a number of values of r sufficient to give a reasonable representation of the relationship between the variance and r. Since s_{II}^2 for any r is the same as s_{III}^2 for $2r$, both variances can be represented on the same diagram (Fig. 1). For systematic sampling, using $k = 4$, it was impossible to go beyond $r = 58$, but for reasons which will soon appear many values of r not used for random sampling were analysed. Fig. 2 shows the relationship between s_{IV}^2 and r.

TABLE I. *Estimates of variance per strip for Debra Dun, for sampling of 1 in r*

[In units of 1,000 (cu. ft. per acre)^2]

r	s_{II}^2	s_{III}^2	s_{IV}^2	r	s_{II}^2	s_{III}^2	s_{IV}^2
2	45·4	33·4	25·1	28	131·4	117·6	86·7
3	59·4	31·4	25·4	30	130·5	122·9	104·5
4	68·9	45·4	21·2	32	142·3	130·6	135·9
5	81·3	49·5	28·3	34	..	..	220·3
6	98·0	59·4	29·3	36	147·7	130·1	201·4
7	92·5	63·7	33·0	38	..	..	107·6
8	119·6	68·9	31·3	40	140·8	132·5	77·1
9	116·8	84·9	36·7	42	..	..	90·6
10	110·3	81·3	42·9	44	..	..	120·4
12	115·7	98·0	69·8	46	..	..	129·8
14	117·6	92·5	82·8	48	161·8	150·3	123·7
15	122·9	104·1	96·2	50	149·0	137·8	210·0
16	130·6	119·6	135·7	51	..	..	243·2
17	..	..	158·2	52	..	..	241·2
18	130·1	116·8	149·0	54	..	..	152·9
20	132·5	110·3	64·6	56	148·0	131·4	65·0
22	..	118·9	45·4	58	..	..	45·7
24	150·3	115·7	79·1	60	153·3	130·5	..
25	137·8	109·6	92·0				
26	..	..	85·1				

The random sampling variances show steady increases as r increases, and for large values of r there is little difference between s_{II}^2 and s_{III}^2. Over the range of r studied, representation of the dependence of s^2 on r by a linear relationship between their logarithms (which seemed satisfactory for Mount Stuart and

Blacks Mountain) would obviously be insufficiently close to the truth. Indeed, no simple mathematical model seemed adequate to describe the relationship; a smooth curve could be drawn through the points of Fig. 1, however, and for the

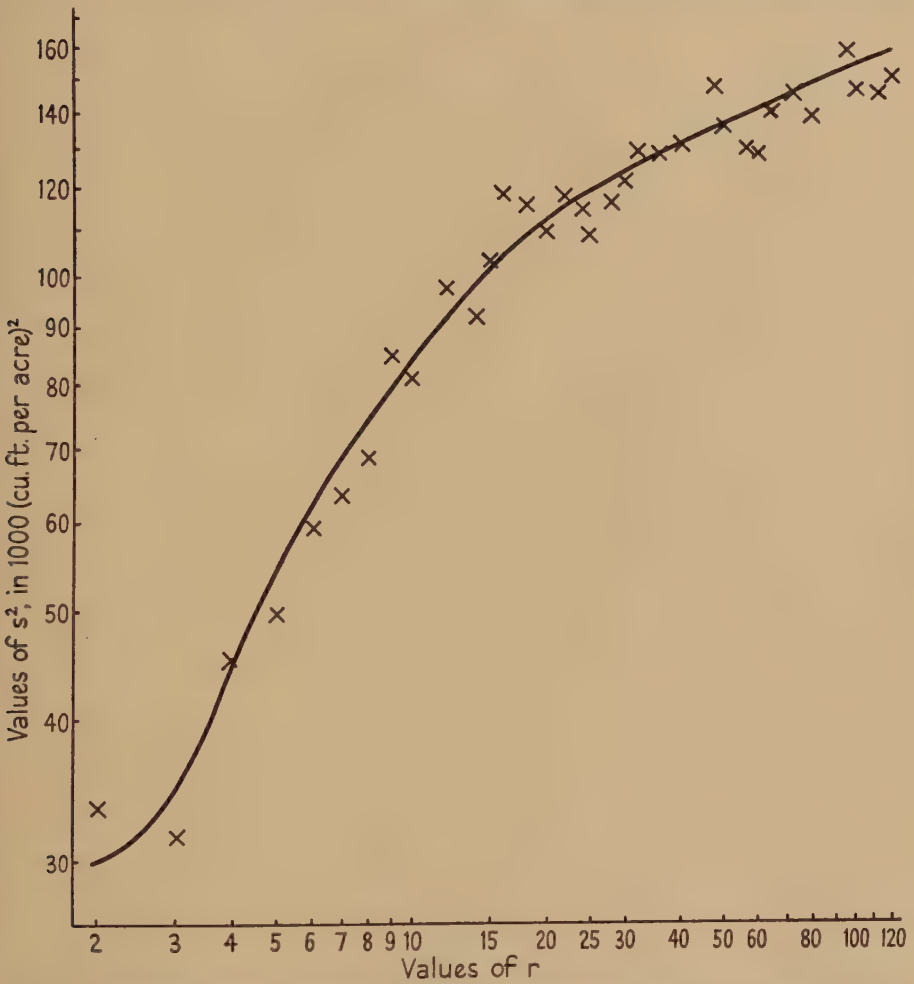

FIG. 1. Relationship between variance, s^2, and r, for random sampling at an intensity of 1 in r stratified in blocks of r strips (Type III); for sampling at the same intensity, but with stratification in blocks of $2r$ (Type II), read the figure for $2r$ instead of r. (The scales of s^2 and r are logarithmic.)

subsequent discussions of sampling efficiency variance estimates S^2_{II} and S^2_{III} have been read from this curve.

Inspection of Fig. 2, or of the last column of Table I, shows that the variance per strip in systematic sampling has a still more complicated relationship with r. In general, s^2_{IV} increases as r increases; superimposed on this trend, however, are large increases in the neighbourhood of $r = 17$, $r = 34$, and $r = 51$, and decreases in the neighbourhood of $r = 22$, $r = 40$, and $r = 58$. This is strongly indicative

of a regular periodic variation in the volume per strip, with period about 17. Periodicity might indeed have been suspected from results presented by Griffith. In his report on the Dehra Dun data [1947 (3)] he showed the means for the eight possible $2\frac{1}{2}$ per cent. enumerations and the sixteen possible $1\frac{1}{4}$ per cent. enumerations, or 1 in 8 and 1 in 16 systematic samples in the terminology of this paper. Not only were the 1 in 16 means very much more widely dispersed than the 1 in 8 (the range from highest to lowest being 300 instead of 100, a change much greater than would be expected on halving the intensity of the sampling), but of the 1 in 16 samples the six whose means exceeded the general mean were consecutive. The phenomenon is emphasized rather more strongly by examining the seventeen 1 in 17 samples, because 17 seems closer to the true period. Table II shows the means of each of the seventeen systematic samples at this intensity. These present an even greater dispersion: the difference between the highest and the lowest is 535, and the seventeen values are much more discrepant than would be stratified random samples at the same intensity. Moreover the sequence of means clearly suggests a regular cycle of variation, samples 5–9 being particularly high and samples 13–17 particularly low.

TABLE II. *Mean volume per strip for 1 in 17 systematic samples of Dehra Dun (in cu. ft. per acre)*

Sample beginning with strip no.	*Mean volume*	*Sample beginning with strip no.*	*Mean volume*
1	943	11	974
2	953	12	913
3	1,078	13	871
4	1,119	14	872
5	1,267	15	887
6	1,185	16	779
7	1,314	17	879
8	1,282	General mean	1,028
9	1,101		
10	1,072		

Standard error for mean of 1 in 17 stratified random samples (Type III) would be approximately 80.

Undoubtedly then, the 292 strips of Dehra Dun show periodicity, with a sequence of rise and fall in volume of timber repeated every seventeen strips (i.e. every 85 strips of the whole area). The regularity is obscured by other sources of variation; it is not apparent when the whole set of 292 strip values is read but is made clear by the averaging process that produced Table II. No explanation of this phenomenon can be offered. Of course, it could arise from a regular variation in some soil or topographical feature, but inquiry from those who know the region has failed to disclose any tendency for hills and valleys to occur regularly at 170–chain intervals over the 36 miles of forest sampled! There may be some reason connected with the nature of the region or with the method of sampling,

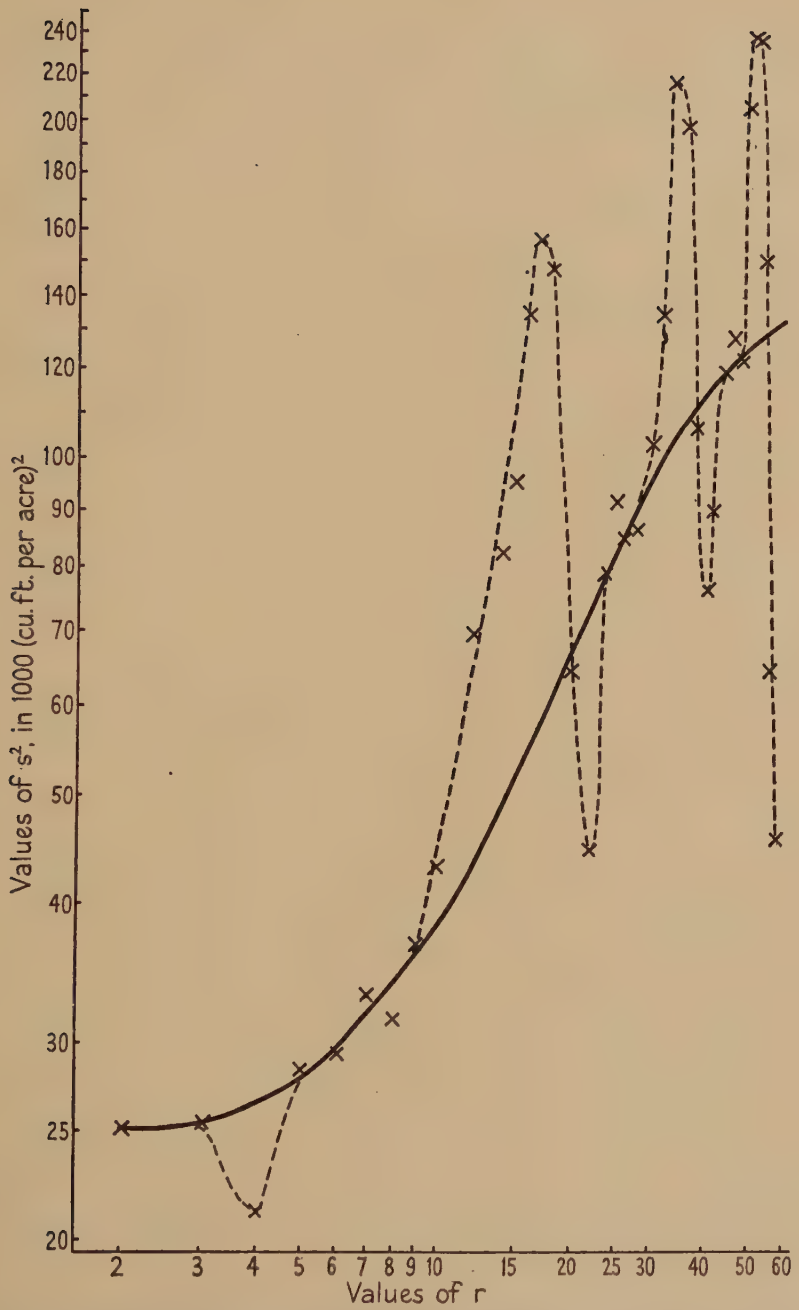

FIG. 2. Relationship between variance, s^2, and r, for systematic sampling at an intensity of 1 in r (Type IV). The continuous curve represents what is described in the text as the non-periodic relationship, the broken curve the relationship allowing for the periodic component. (The scales of s^2 and r are logarithmic.)

but it is unlikely that any simple explanation of this kind can be found. Alternatively, the periodicity may be in a sense a chance or accidental effect. The complexity of interactions between trees growing close to one another, generally classified under the single heading of 'competition', makes the timber volumes on neighbouring strips dependent upon one another, so that the series of strip values is 'autocorrelated'. In a short series—and statistical theory suggests that series very much longer than 292 terms may be 'short' in that they are liable to behave atypically—the true character of the autocorrelations may fail to be completely manifested, and may appear by chance in over-simplified form. It is scarcely to be believed that the type of competition in growth present in the Dehra Dun forests necessarily produces a simple periodicity of length 170 chains, but the chance circumstances of this particular region may have happened to give prominence to this component of a much more complex pattern.

Further speculation on the origin of the periodicity seems useless. The chief concern in this paper is to consider its effect on sampling. In Fig. 2 the steady increase in variance as r increases is disturbed by prominent maxima when r is nearly a multiple of the period, 17. As is well known, systematic sampling is of low precision if the interval between successive units is in step with a periodicity, so that all the units of one sample tend to be near a peak or all near a trough of the cycle. On the other hand, if the interval between units is about 1·5, 2·5, 3·5,... times the period, the variance may be expected to be excessively low, since a strip that happens to be at a peak of the cycle will be followed by one in a trough, and vice versa. An effect of this kind is apparent in Fig. 2, the variance being low near $r = 22, 40, 58$; these minima are less pronounced than the maxima, and occur rather earlier than the half-period, presumably because of some asymmetry in the form of the cycle.

A smooth curve has been drawn in Fig. 2, as in Fig. 1, entirely by eye, to represent the general trend of the points, but points which appear to have been affected by the periodicity have been ignored. This might seem to introduce a strong subjective element into the drawing of the curve. In fact, the curve has been drawn to have a form similar to that of Fig. 1, concave upwards for low values of r and convex upwards for large r, for it is reasonable to suppose that the variance will not increase indefinitely as r is increased. With this restriction, and a concave portion extending rather farther than in Fig. 1, a number of the points indicate a curve very satisfactorily. The curve may be regarded as a representation of the variance in systematic sampling if there were no periodicity, and it is in some respects more suitable for comparison with variances in random sampling, in a general evaluation of the precision of the two types of sampling, than would be a curve which allowed for the periodic component.

The data seem insufficient to indicate any mathematical model for the periodic variation: without this, any discussion of the precision of sampling when allowance is made for periodicity must be little better than speculation. In order to provide smoothed values for variances, a modified curve has also been drawn in Fig. 2 so as to pass as closely as possible through the points affected by the periodicity. This curve has been constructed to have maxima at $r = 17, 34, 51$, and minima

at 5–7 units after the maxima, or at $r = 22, 40, 58$; between the regions where the periodicity has a marked effect, the curve is taken to be identical with the first curve. A difficulty arises at $r = 4$, for which s^2_{IV} was appreciably lower than for $r = 2$ and $r = 3$. Is this merely chance variation from the non-periodic curve, or is it another manifestation of sub-normal variation where the sampling interval exceeds a multiple of 17 by 4–5 units? The non-periodic curve may be drawn so very satisfactorily through the points for $r = 2, 3, 6$ that the second explanation seems more plausible, and for the periodic curve a minimum has been incorporated at $r = 4$. The periodic curve must not be regarded as more than a qualitative indication of the effects of the periodicity. Even if the already extensive calculations were increased so as to give values of s^2_{IV} for other intensities of sampling, the curve for so complex a relationship could scarcely be determined sufficiently exactly from these data to give a satisfactory quantitative assessment; from the empirical curve in Fig. 2, smoothed values of s^2_{IV} may be derived, on which may be based a discussion of the periodicity in qualitative terms.

In all that follows, the empirical variances shown in Table I will be replaced by smoothed values, for which

$$S^2_I = 207{,}400,$$

S^2_{II} and S^2_{III} are read from Fig. 1, and S^2_{IV} is read from Fig. 2. Unless the contrary is explicitly stated, S^2_{IV} relates to the non-periodic curve.

THE COMPARISON OF SAMPLING PROCEDURES

Random and systematic sampling may now be compared for Dehra Dun in several different ways, exactly as was done previously for Mount Stuart and Blacks Mountain [1948 (2)].

The percentage efficiency of systematic sampling relative to stratified random is shown in Fig. 3. Except for large values of r, S^2_I is so much greater than S^2_{IV} that the efficiency of systematic sampling relative to unrestricted random is high, being substantially over 300 per cent. when r is less than 20. Type II stratification compares more favourably with systematic, and Type III is better still, but even relative to these two types, systematic sampling is more than twice as efficient for most values of r less than 20. As was found for Mount Stuart and Blacks Mountain, at very low sampling intensities the difference in efficiency between systematic and either form of stratified sampling seems practically to disappear. A phenomenon not previously observed is the relative improvement in the efficiency of random sampling at very high intensities ($r < 8$). Dehra Dun in general shows a lesser relative efficiency for random sampling than the forests previously analysed. Even under the most unfavourable conditions neither Mount Stuart nor Blacks Mountain showed either form of stratified random sampling to be less than half as efficient as systematic.

Fig. 3 shows the relative efficiencies of three forms of sampling for a forest like Dehra Dun but without periodic variation. If the modified curve in Fig. 2 is used to give smoothed variances, S^2_{IV}, which include the periodicity, a new set of relative efficiencies may be calculated, and these are represented in Fig. 4. It must

again be emphasized that the details of the curves are somewhat speculative, and only their qualitative characteristics can be regarded as trustworthy. The low efficiency of systematic sampling when the sampling interval is nearly a multiple

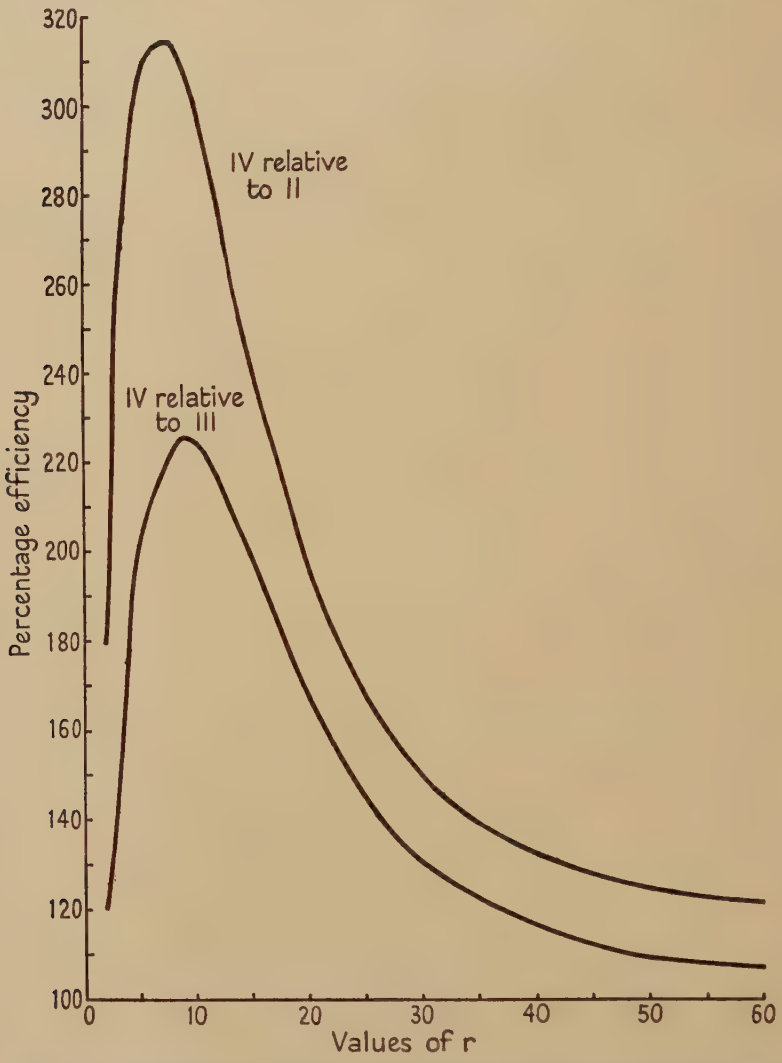

Fig. 3. Efficiency of systematic sampling, IV (non-periodic), relative to stratified random, II and III, at a sampling intensity of 1 in r. Upper curve: IV relative to II. Lower curve: IV relative to III.

of the period is to be expected on general principles, and Fig. 4 suggests that in the Dehra Dun forest periodicity was sufficiently marked to make the efficiency substantially less than for stratified random sampling at the same intensity. On the other hand, when the sampling interval exceeds a multiple of the period by a few units, the efficiency will be higher than in the absence of a periodic

component. The dependence of the efficiency upon r is therefore represented by 'wavy' curves.

Fig. 5 shows the intensity of sampling necessary with any one of the three types of random sampling in order to obtain the same precision as by systematic sampling at a specified intensity. These are very like the corresponding curves for

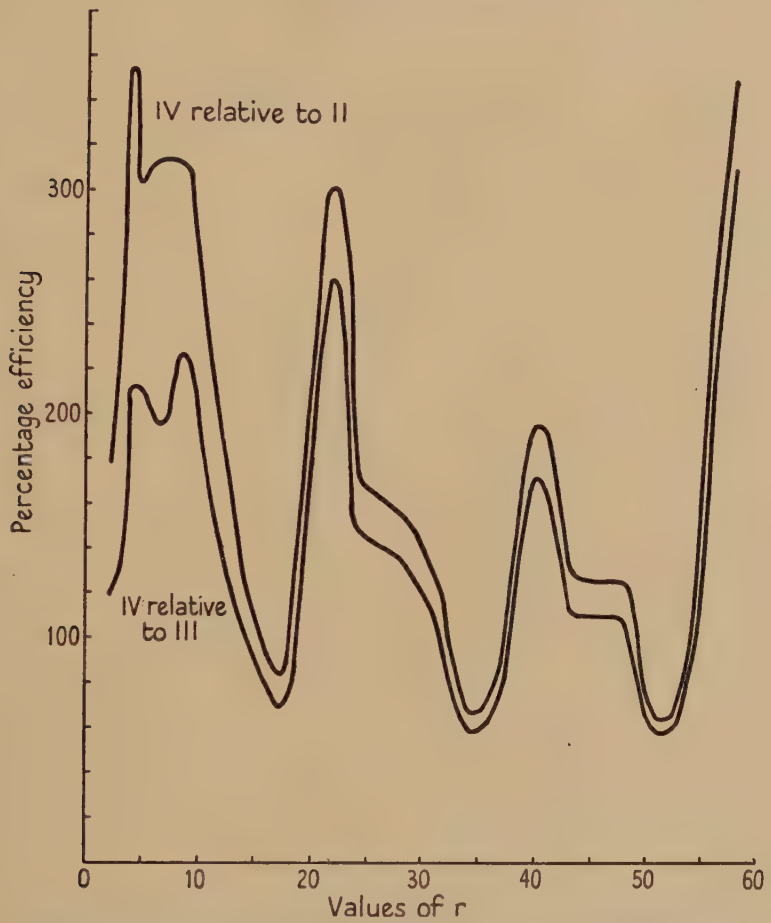

Fig. 4. Efficiency of systematic sampling, IV (periodic), relative to stratified random, II and III, at a sampling intensity of 1 in r. Upper curve: IV relative to II. Lower curve: IV relative to III.

Mount Stuart and Blacks Mountain. Inclusion of the periodic component would modify the curves and again produce maxima at 17, 34, 51. However, it is scarcely important to show that, whereas a 1 in 20 stratified sample would be as precise as a 1 in 17 systematic, to obtain the precision of a 1 in 22 systematic sample a 1 in 10 stratified would be needed! The modified curves are therefore not shown.

The percentage standard error per strip, adjusted for finite sampling, namely

$$\frac{100S\sqrt{(1-1/r)}}{1028{\cdot}4},$$

is shown in Fig. 6 for each of the four types of sampling. Again the curves are similar to those for the other forests, except that for Dehra Dun all the standard errors are rather larger and the advantage for systematic sampling more marked. The 'wavy' curve which would allow for the periodicity has not been drawn.

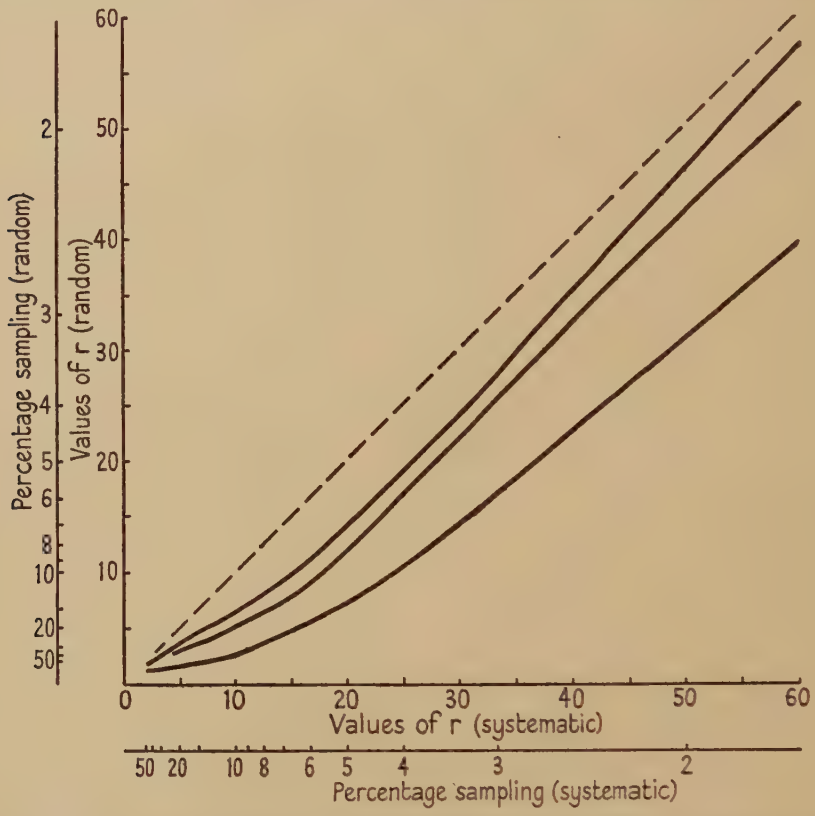

FIG. 5. Sampling intensity necessary with random selection, I, II, or III, in order to give same precision as a specified intensity with systematic selection, IV (non-periodic). Lower curve: Unrestricted random, I. Middle curve: Stratified in blocks of $2r$, II. Upper curve: Stratified in blocks of r, III.

(Broken line shows relationship as it would be for all types of sampling if volume per strip varied in a completely random manner, independently of position and of neighbouring strips.)

Table III shows the limits of error in estimation of mean volume, to be expected on an average in sampling at various intensities by each of the methods under discussion. The three sampling intensities chosen for illustration give total numbers of strips per sample about the same as in the illustrations used for Mount Stuart and Blacks Mountain. Stratification improves the precision very considerably, as compared with Method I, unrestricted random sampling. The two forms of stratified sampling do not differ greatly in their limits of error, but there is a further gain if systematic sampling is substituted for stratified random (especially for very intensive sampling), at least if no periodic component is present. The 1

in 16 and 1 in 32 samples, however, happen to be intensities at which the effect of the periodicity is very noticeable, so that for the genuine Dehra Dun data (by contrast with the idealized non-periodic results) systematic sampling is no better than either form of stratified.

TABLE III. *Percentage limits of error for Dehra Dun*

Sampling intensity	1 in 8		1 in 16		1 in 32	
No. of strips in sample	36		18		9	
Probability of error	0·05	0·01	0·05	0·01	0·05	0·01
Sampling method:						
Unrestricted random (I)	13·5	17·8	19·8	26·0	28·5	37·4
Stratified random (II)	9·7	12·7	15·5	20·4	23·9	31·4
Stratified random (III)	8·1	10·7	14·2	18·6	22·3	29·3
Systematic (IV) non-periodic	5·5	7·2	10·2	13·4	19·8	26·0
Systematic (IV) periodic	5·5	7·2	16·0	21·1	23·1	30·3

DISCUSSION

Two aspects of the Dehra Dun results are of interest in the general study of forest sampling. In a previous paper [1948 (2)] tentative conclusions on the merits of different sampling methods were based on data from only two forests, though it was recognized that considerably more evidence was desirable. As has already been pointed out, Dehra Dun is not entirely satisfactory for this purpose, because the 292 strips for which records are available are not contiguous but are themselves a 20 per cent. systematic sample. The precision of any form of sampling from these strips might be expected to be less than for a corresponding sampling from 292 consecutive strips. Fig. 6 and Table III support this view: on comparison with the corresponding diagrams and tables for Mount Stuart and Blacks Mountain [1948 (2)], percentage standard errors and limits of error are seen to be everywhere greater. If the periodicity is disregarded, systematic sampling again proves more precise than any form of random sampling, and the advantage of systematic over either stratified random method is greater than for the other two forests. Fig. 5 shows that a 30–50 per cent. increase in sampling intensity may be needed in order to obtain a random sample as precise as a specified systematic sample. How far this is due to the non-contiguity of the strips cannot be said, but the conclusion tentatively advanced previously [1948 (2)], that suitable stratification would give results almost as precise as a systematic sample, must now be considered as possibly over-optimistic.

The second important feature of Dehra Dun is the periodicity. No certain explanation of this can be given, and it may be little more than an accidental circumstance that a comparatively short series of values should behave in the manner shown in Table II. If many statistical investigations of this kind, involving detailed analyses of series of records for systematic sampling at different intensities, were undertaken, occasionally chance alone would produce an appearance of

periodicity. That the Dehra Dun records do show a period of 17 strips or 170 chains is a fact that inspection of Table I and Fig. 2 leaves in no doubt. In practice only a very unfortunate coincidence would lead to occurrence of a periodicity and

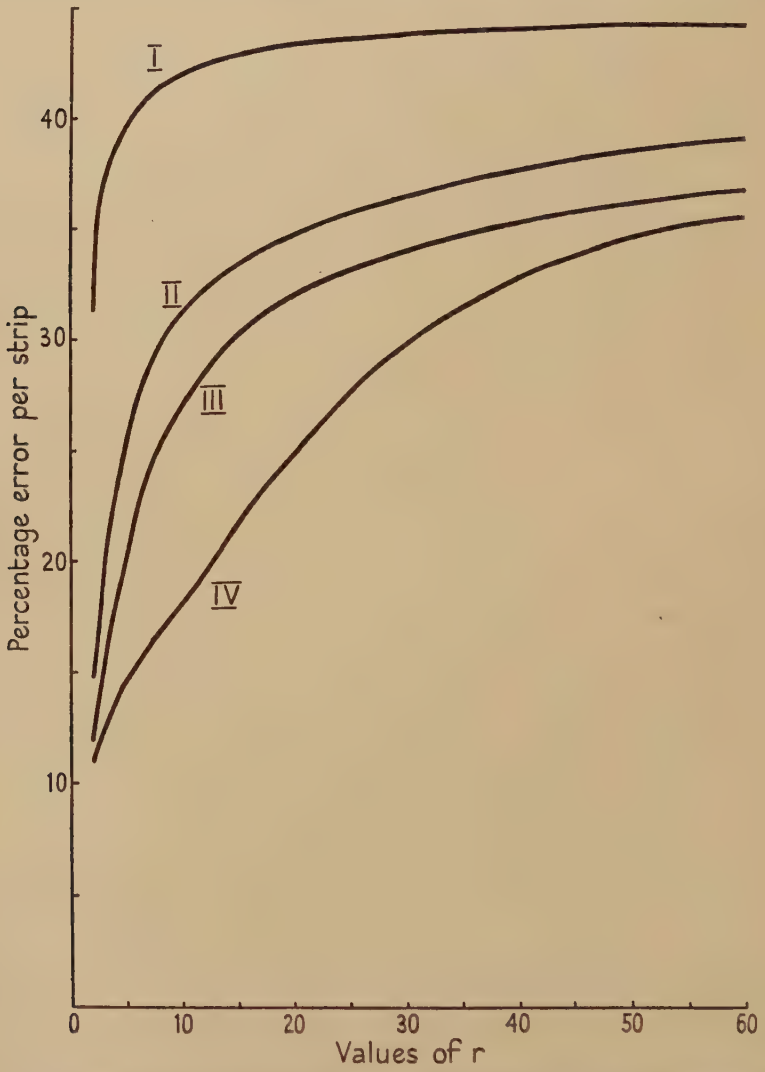

FIG. 6. Percentage error per strip for four sampling procedures, I, II, III (all random), and IV (systematic, non-periodic).

the choice of a multiple of the period as the sampling interval. (Of course, in a forest for which regular planting, or some exceptional topographical regularity, makes periodicity likely, care should be taken to avoid the use of any sampling interval which is a multiple of the expected period.) Such a coincidence might be accepted as one of the hazards of systematic sampling. It will be rare, but if it

occurs the sample will be much less precise than was hoped—for Dehra Dun as low as for stratified random sampling (Method II), and perhaps relatively worse in other forests. Moreover, no clue to the presence of periodicity will be found in the sample itself: rather the contrary, indeed, for the constituent strips of the sample will tend to be in particularly close agreement with one another [1947 (1)].

It has already been emphasized [1947 (1), 1948 (2)] that a decision to adopt systematic sampling is in general an acceptance of the opinion that no internal estimate of sampling error is needed, for there is little hope of forming a valid estimate from the sample. The danger that precision may be upset by periodicity, and that the sample data may not arouse any suspicion of this, must now also be recognized. These are not necessarily condemnations of systematic sampling, the arguments for which have been adequately presented elsewhere. What is essential is that anyone who adopts systematic sampling in forestry should be fully aware of its dangers, as well as of its virtues, and should not (as so often in the past) accept facile arguments in its favour yet expect to obtain also the alternative merits of random sampling. Table III and corresponding tables in the previous paper make clear that, though systematic sampling tends to be more precise, a stratified random sample with two units per block will usually be of comparable precision and not so poor that its considerable merits must be disregarded because of any overwhelming superiority of the systematic scheme.

In an important paper [1948 (5)] Yates has recently discussed the theory of systematic sampling, and has examined several series of data by methods similar to those used here. The introduction and conclusions of his paper should be read by all concerned with the practice of sampling, even though they may find the main body of the theory beyond their mathematical competence. Yates states that his investigation 'confirms that no method of obtaining a really valid estimate of error from the sampling results themselves can be hoped for' in systematic sampling. He points out that, whereas 'random sampling can be applied with complete confidence to material about which nothing is previously known', if systematic sampling is adopted 'unsuspected periodicities in the material may lead to grossly misleading results'. If something is already known about the variability of the material to be sampled, or if the projected investigation is so extensive as to justify a preliminary study of some part of the material purely as an aid to the planning of the main sample, systematic selection of the sample becomes more worthy of consideration.

The next best thing to an unbiased estimate of the standard error of a systematic sample would be an upper limit to that error which was not so large as to be useless. For many practical purposes the investigator would be quite content to state that his error was not greater than some known quantity, provided that the limit was reasonably near to the true value. A suggestion from Yates indicates how such an upper limit might be obtained from the records of a single systematic sample, if the variation between strips (or other sampling units) were predominantly random. As has often been emphasized, however, timber volumes on successive strips of a forest are not randomly distributed. Even to obtain an upper limit for the error then requires some supplementary sampling. Yates has suggested either

additional randomly located systematic samples over part of the material, or, again only for part of the material, taking additional sampling units at $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ of the interval between successive units of the main sample. He has illustrated the use of the supplementary data. It is doubtful whether this ingenious proposal can be used to much advantage in forest sampling, except for very large tracts of forest. If the estimates of the components of variance are to be trustworthy, they must be based upon a reasonable number of degrees of freedom, and therefore there will be a lower limit to the amount of supplementary sampling that is worth while, irrespective of the size of the whole investigation. Unless the main sample consists of 100 or more strips, the supplementary data required for the assessment of error are likely to be proportionally so great as to raise the question of whether a random sample, with an equal or lesser *total* number of strips, would not be both more economical and more satisfactory. If sampling intensities of the order of 5 per cent. are under consideration, this means that the whole forest must contain 2,000 or more strips before supplementary sampling for the assessment of the precision of a systematic sample becomes an economic proposition.

SUMMARY

The methods of a previous paper have been applied to the study of alternative methods of sampling certain Dehra Dun forests of northern India, for the estimation of timber volume. The data available are records of an enumeration of every fifth strip of these forests, and different schemes for sub-sampling from this sample have been considered.

The data show clear evidence of periodic variation, the period being about 170 chains in length. This has important effects on the relative precisions and efficiencies of different types of random and systematic sampling. In general, systematic sampling was more precise than any form of random sampling at the same intensity, but this property was violently upset if the interval between successive strips of the systematic sample was a multiple of the period. The importance of this to the practice of systematic sampling, and to the problem of assessing the standard error of an estimate based upon a systematic sample, has been discussed. The conclusions must be accepted with reservations, however, because the data on which they are based relate only to a 1 in 5 sample of the forest.

Recent work by Yates has given some theoretical guidance on how to assess an upper limit to the error of a systematic sample. Unfortunately, this seems unlikely to be of great use in forest sampling because of the amount of supplementary data required. Except perhaps for very large forests, the investigator is still forced to choose between a random sample, for which he can assess the precision, and a systematic sample, probably but not necessarily more precise than the random and failing to give any reliable information on its own precision.

ACKNOWLEDGEMENTS

I am greatly indebted to the President of the Forest Research Institute, Dehra Dun, India, and to Dr. A. L. Griffith (lately Silviculturist to that Institute) for permitting me to use the data on which this paper is based. Dr. Griffith has also

most generously assisted me in correspondence explaining doubts and difficulties relating to the data.

The extensive calculations for this and the previous paper have been carried out by my computing assistants. I should like to take this opportunity of expressing my gratitude to them for their care and patience in a very tedious task.

LITERATURE REFERENCES

(1) Finney, D. J. (1947): 'Volume Estimation of Standing Timber by Sampling.' *Forestry*, xxi. 2, 179–203.

(2) —— (1948): 'Random and Systematic Sampling in Timber Surveys.' *Ibid.*, xxii. 1, 64–99.

(3) Griffith, A. L. (1947): *The Efficiency of Enumerations.* XV, Sal (*Shorea robusta*) *Forest in Dehra Dun Division of the United Provinces.* Forest Research Institute, Dehra Dun, Indian Forest Leaflet, No. 96.

(4) Sahai, R. (1947): 'Partial Enumeration in the Dehra Dun Forest Division.' *Indian Forester*, lxxiii. 437–44.

(5) Yates, F. (1948): 'Systematic Sampling.' *Philos. Trans.* A, ccxli. 345–77.

THE RESISTANCE OF WOOD-ROTTING FUNGI TO DESICCATION

By W. P. K. FINDLAY

(Department of Scientific and Industrial Research, Forest Products Research Laboratory)

INTRODUCTION

WHEN wood in a building or other structure is found to be decayed, the question as to when it was infected is often raised. Although there are a few fungi that can infect timber at any stage from the tree to the finished article, generally speaking there are certain species more or less confined to growing trees, whilst others are typically enemies of timber in storage. If decay is found to have been caused by a fungus from one or other of these groups, it must be presumed that the fungus has remained alive during the period of seasoning, either in an active or in a dormant condition.

With the exception of timbers used in very large dimensions, such as large oak beams, it is unusual to employ wood in an unseasoned condition. It is therefore of interest to know just how long wood-rotting fungi can remain active in air-dry material.

While fungi vary in their moisture requirements, few can make any growth in wood containing less than 22 per cent. moisture, and none of the wood-rotting types can continue their development in wood that contains less than 20 per cent. of moisture.

EXPERIMENTAL WORK

Experiments have been carried out to determine how long fungi can remain alive in air-dry wood. Blocks of wood measuring $5 \times 1\frac{1}{2} \times 1\frac{1}{2}$ inches were infected with pure cultures of various wood-rotting fungi. After approximately four months' exposure to the fungi the blocks were removed from the culture tubes, when it was found that they were appreciably decayed and permeated throughout with mycelium.

The following fungi and timbers were used in the tests:

Merulius lacrymans (Wulf.) Fr., on Sitka spruce (*Picea sitchensis* Carr.).
Lenzites sepiaria (Wulf.) Fr., „ „
Lenzites trabea (Pers.) Fr., „ „
Poria monticola Murr.[1] „ „
Lentinus lepideus Fr., on Scots pine sapwood (*Pinus sylvestris* L.).
Polystictus versicolor (Linn.) Fr., on beech (*Fagus sylvatica* L.).

After removal from the cultures the spruce blocks were kept for one month in an atmosphere maintained at 90 per cent. relative humidity and then distributed

[1] Formerly considered a form of *Trametes serialis* Fr.

into constant humidity chambers maintained at different humidities. The pine and beech blocks were transferred, after one day's drying in the laboratory, directly to the various humidity rooms, as the preliminary storage in the 90 per cent. relative humidity chamber was found to encourage subsequent growth of extraneous moulds.

The humidity rooms were maintained throughout the whole of the test at 25° C. (77° F.) and at 90 per cent., 75 per cent., 60 per cent., and 45 per cent. relative humidities, respectively.

After varying intervals of time samples were removed from the humidity rooms and cultures were prepared from them by removing plugs of wood from the interior of the blocks by means of an increment borer, and placing these in tubes of malt agar medium.

During the first 6 months the vitality of the fungi was tested at monthly intervals and subsequently at quarterly intervals until after 3 years when tests were made annually.

Contamination with moulds of the blocks stored in the chamber kept at 90 per cent. relative humidity became troublesome in the later stages, but it was usually possible to determine whether fungus remained alive in the block by soaking a whole block in water and observing whether any mycelium of the test fungus appeared on it.

RESULTS OBTAINED

		Maximum period of storage after which growth has been observed			
Relative humidity of storage room . . .		90%	75%	60%	45%
Approximate moisture content of wood as percentage of oven-dry weight		22–23%	about 16%	about 12·5%	about 10·5%
Test fungus	*Timber*	*Months*			
Merulius lacrymans . . .	Sitka spruce	3	4	4	3
Lenzites sepiaria	,,	32	39	57+	60+
Lenzites trabea	,,	39	39	64+	64+
Poria monticola . . . . (formerly considered a form of *Trametes serialis*)	,,	10	10	13	13
Lentinus lepideus	Scots pine	29	41	41	41
Polystictus versicolor . . .	Beech	61+	57	57	61+

It should be noted that living fungus was still present at the time of writing in some of the blocks infected with *Lenzites sepiaria*, *L. trabea*, and *Polystictus versicolor*, so that their maximum periods of survival under the conditions of this test have not yet been determined.

DISCUSSION OF RESULTS

It must be concluded that a number of species of wood-rotting fungi can survive for long periods (exceeding 5 years) in air-dry wood conditioned to a moisture

content of approximately 12 per cent.; a conclusion in conformity with the results obtained by Scheffer and Chidester [1948 (2)]. It will be noted that the observed period of survival of some species was greater in the blocks kept at the lower humidities than in those kept in the 90 and 75 per cent. relative humidities. It is difficult to say if this is a true result, for some of the blocks at the higher humidities became permeated with moulds, and these moulds may have obscured the growth of the wood-rotting Basidiomycetes. It is likely, however, that once mycelium has gone into a resting condition, i.e. when the moisture content of the substratum is too low for its continued growth, its chance of continued survival is better under really dry conditions that prevent the growth of other organisms, which may inhibit renewed activity of the wood-rotting forms on re-wetting or may actually attack and decompose the resting mycelium. However, even in the absence of other organisms, the survival of resting protoplasm is favoured by the absence of moisture, a fact that is used in the freeze-drying process for the preservation of micro-organisms.

The temperature at which the test blocks were stored probably influenced the results, especially those obtained with *Merulius lacrymans*, for it was above the optimum temperature for the growth of this fungus; and there are reasons for believing that it can, under practical conditions, survive longer periods of desiccation than those of this test. It is planned to repeat the experiments with *Merulius* at a lower temperature.

It is likely that the very short period of survival noted for *Coniophora cerebella* by Scheffer and Chidester [1948 (2)] was influenced by the high temperature (80° F.) at which the blocks were stored, for the optimum temperature for the growth of this fungus is only 23° C. (73° F.). It is well known that cool conditions of storage tend to prolong the survival period of fungi and bacteria in culture, as well as that of the seeds of higher plants. It is therefore likely that the length of time during which certain fungi can remain alive in dry wood kept under relatively cool conditions may considerably exceed the figures given in this paper and in that by Scheffer and Chidester.

It is possible that storage of fungi *in vacuo* may greatly extend their life. Bisby [1945 (1)] reported that pilei of *Schizophyllum commune* Fr. that had been sealed up in vacuum tubes in 1909 were still alive and capable of shedding spores in 1945—a period of storage of 35½ years, but how much this exceeds the longevity of the same species stored in dry air is not known. Buller found that pilei of this fungus were still alive after 6¼ years' storage in a very dry room.

PRACTICAL IMPLICATION OF RESULTS

It is evident from the results of these and other tests that simple air-drying cannot be relied upon to kill, within a reasonable period, fungal infection present in timber. The chances of a fungus resuming activity when the wood in which it is growing is re-wetted depend very largely on the species involved. Generally speaking, the most resistant fungi are those that occur in nature on timber which is fully exposed to the weather and becomes dried out at regular intervals, such, for example, as *Lenzites sepiaria* (Wulf.) Fr. (the commonest species on softwood

fencing in many parts of Europe) and *Polystictus versicolor* (Linn.) Fr. These xerophytic species are able to resume activity whenever conditions become sufficiently moist, and then go into a dormant condition without suffering damage whenever the substratum dries out.

The so-called dry rot fungi, such as *Merulius lacrymans*, that normally live in sheltered positions, do not appear to be highly resistant to desiccation, but under practical conditions they can probably remain alive for at least a year in comparatively dry conditions in a house. Where large-sized timbers are in contact with thick brick or masonry walls, their drying out after the source of dampness has been removed may be greatly retarded and the fungus may remain alive for considerable periods. More accurate data on the survival period of *Merulius* in air-dry materials are needed.

Wherever it is desired to use timber that is known to have been infected even to a slight degree with wood-rotting fungi, it should be sterilized either by treatment under pressure with a wood preservative or by heat treatment in a timber-drying kiln. The temperatures required to kill wood-rotting fungi in a saturated atmosphere are known, and these can generally be applied without risk of injuring the wood, provided the atmosphere in the kiln is kept sufficiently humid to prevent drying out and shrinkage of the wood. Desiccation alone cannot be relied upon to kill latent infection in wood.

SUMMARY

The survival of wood-rotting fungi in air-dry wood has been studied by keeping samples of pine, spruce, and beech infected in the laboratory with pure cultures of *Merulius lacrymans* (Wulf.) Fr., *Lenzites sepiaria* (Wulf.) Fr., *Lenzites trabea* (Pers.) Fr., *Lentinus lepideus* Fr., and *Polystictus versicolor* (Linn.) Fr. in constant humidity rooms maintained at 90, 75, 60, and 45 per cent. relative humidity for periods up to 5 years. Cultures were prepared from these samples at regular intervals. It was found that *Lenzites sepiaria*, *L. trabea*, and *Polystictus versicolor* were still alive after 5 years' storage in an atmosphere of 45 per cent. relative humidity at 25° C., i.e. in wood having a moisture content of about 10·5 per cent. It is concluded that air-drying cannot be relied on to kill fungi in wood.

ACKNOWLEDGEMENT

This work has been carried out as part of the programme of the Forest Products Research Board and is published by permission of the Department of Scientific and Industrial Research.

LITERATURE REFERENCES

(1) Bisby, G. R.: 'Longevity of *Schizophyllum commune*.' *Nature*, clv. 732, 1945.

(2) Scheffer, T. C., and Chidester, M. S.: 'Survival of Decay and Blue Stain Fungi in Air Dry Wood.' *Southern Lumberman*, 15 December 1948.

SOCIETY'S AND OTHER NEWS

EXCURSION AND ANNUAL GENERAL MEETING, 1950

PRELIMINARY arrangements have been made to hold the 1950 excursion in Argyll, with headquarters in Oban, from 25th to 29th September. Three days will be spent in visiting State and private forests. The 23rd Annual General Meeting will be held in Oban during the excursion.

CHANGES OF ADDRESS, &c.

MEMBERS are reminded that they should intimate changes of address to the Secretary in order to have their Journals and other communications delivered promptly. Changes of rank should also be intimated, so that the records may be kept up to date.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE FORESTRY SUB-SECTION K*

BIRMINGHAM, *30th Aug.–5th Sept.*, 1950

A PARTICULARLY interesting programme has been arranged, including the presence as guests of two leading figures in Forest Genetics, Prof. Syrach Larsen of Denmark and Prof. Bertil Lindquist of Sweden. The discussions and papers will be of major importance to British foresters able to attend or to study subsequently the written records.

HONOURS

THE award of the C.B. to Mr. A. H. Gosling, Director-General of the Forestry Commission, is a welcome recognition of his great services and responsibilities to British forestry.

MISCELLANEOUS

THE Clarendon Press, Oxford, finds a shortage in its complete sets of *Forestry* in respect of Vol. VII, No. 1, through a packing error made some years ago. They wish to buy back a few copies of that issue, to complete their sets. Any who are willing to help in this matter are asked kindly to write to the Clarendon Press, Oxford.

ANNUAL EXCURSION OF OCTOBER 1949 BASED ON HEREFORD

THE fourth post-war excursion was held at Hereford from 4th to 6th October 1949. About 57 members attended. The accommodation and transport of all those who wish to attend, and adequate demonstrations in the woods visited, now tax the organizers' resources; but the value of these meetings and free discussions is certainly great. There was a particularly useful admixture of private and State foresters in the attendance, and of silviculturists with those primarily interested in utilization.

Two days were spent in very well managed private forests and one day in a specially interesting State forest which is beginning to show promising results in hardwoods as well as conifers. Both the private owners ably demonstrated their own woods, and in the State woods the party was privileged to listen to Mr. Long and other foresters who had tended some of the crops seen as much as 35 years ago. The general arrangements were again admirable, as in 1948. The members are greatly indebted to the chief organizers, Mr. Sangar, Mr. Connell, and Mr. Galloway, and all their collaborators, including Mr. Long, Mr. Ryle, Mr. Russell, and his staff; they are also greatly indebted to the two private owners, Major C. P. Ackers and Sir Richard Cotterell, and to H.M. Forestry Commission, for the demonstrations and facilities in the woods visited.

The second evening of the three full days spent at Hereford was taken up by the 22nd Annual General Meeting. On the third evening, 6th October, there was a good technical discussion, well guided by Mr. Sangar, President of the Society, in the Chair. As usual, there was a healthy divergence of views. The more important points noted in the woods visited, and arising in the evening technical discussion, are recorded below. The general opinion of those present was that, as in 1948, the centre for the meeting had been well chosen and the discussions had been practical.

HUNTLEY MANOR ESTATE (Major C. P. Ackers)

Major Ackers explained on the spot the history and technique of Newent Wood. It was some 650 acres in area and he had bought it in 1910 as a heavily exploited coppice with standards crop of oak, worked on a 17-year rotation. Much of the soil was heavy red clay. Between 1911 and 1926 he clear-felled and replanted all of it, mainly with larch and Douglas fir. The cost of establishing the last 200 acres (1920–6) was just under £8 per acre, including rabbit catching. Almost all the mature timber was cut for the First World War; and in the Second War about half the crop was felled prematurely, and all the remainder big enough for pit timber was heavily thinned, bringing a financial return little more than the present cost of replanting.

The felled areas have been replanted with larch, Port Orford cedar (*Chamaecyparis lawsoniana*), and grand fir (*Abies grandis*). When bought, the wood swarmed with rabbits. By an intensive campaign, using shooting, snaring, trapping, ferreting, and every other method, Major Ackers killed out the rabbits and replanted successfully without fencing, though the adjoining farms and common-land did not belong to him. Douglas fir dominated European larch, where mixed, if the insect pest (*Adelges cooleyi* Gillette), which is apt to affect Douglas fir, left it alone. Where the *Adelges* had attacked and slowed up the Douglas fir, the larch had dominated the Douglas. Some 2-year 1-larch transplants outgrew

2-year 2-larch from the same nursery within 5 years, perhaps because on the heavy clay the check of the transplanting affected the older trees more than the younger. (The local annual rainfall is about 28 inches.) On this clay the Japanese larch starts quickly and soon smothers the weeds; also it is reputed to produce heavy timber which timber merchants during the Second World War found to be as heavy as European larch.

On the subject of larch seed-bearers Mr. Denis Warren, assistant to Major Ackers, pointed out that some individual trees were consistently barren and others fertile. One of the visitors, Mr. Hummel, estimated by eye that a plantation of European larch, 34 years old, was putting on about 100 cu ft. per acre per annum for every foot of height growth, and the crop was growing in height at about 18 inches per annum. Opinion was divided on the case for any underplanting. The thinning in use was estimated to be slightly heavier than the D Grade of the Forestry Commission, and appeared very suitable.

Mr. Warren explained the extraction technique, which included a maximum drag of 100 yards by the owner's own horses and men (3*d*. a cu. ft.) to rough unmetalled tracks. Along these tracks the timber was taken by 4-wheel-drive lorries to the coalmines (10 miles away) or a turnery-works (2 miles away). Birch fetched over £3 a ton at these works. (A Forestry Commission visitor said that their extraction plans now favoured rougher tracks at more frequent intervals rather than infrequent metalled roads.) Major Ackers had reduced dragging, in one fairly level area of this wood, by cutting out every tenth row of trees, yielding many thinnings and allowing lorries to get within a few yards of every log.

He spoke highly of grand fir (*Abies grandis*) as a quick, heavy producer of serviceable timber; but Major Mitchell had had trouble at Kyloe, Northumberland, with cracking in thin boards of this species. Mr. John T. Smith, with much experience of box boards, preferred grand to noble fir, finding the former acceptable. He believed also in the general principle of growing for quality in any saw-timber, instancing the value of first-grade imported softwood being double that of fourth grade.

On Huntley Hill a number of good mixed plantations were seen, formed in 1906–10 by Major Ackers, including Douglas fir 50/50 with European larch or Sitka spruce, and Japanese larch with Corsican pine or clumps of beech. They included a striking example of European larch escaping canker when in mixture with Douglas fir, although adjacent areas of pure larch were badly cankered. Some good high pruning of the larch was demonstrated. It cost about 4*d*. per tree (to 20–5 ft.) now, against 1*d*. formerly. Underplanting was discussed in a 41-year-old Japanese larch plantation. Major Ackers had found Douglas fir very disappointing as an underplant, perhaps because of the low rainfall. It was apt to check under Japanese larch. He favoured western red cedar (*Thuya plicata*) for the purpose. It gave early returns from the sale of foliage and small ladder sides, and was vigorous and wind firm. He was not afraid of butt-rot in the species.

The care and skill evident in the woods seen were much appreciated, and it was clear that a close watch on utilization was kept by the silviculturists concerned.

TINTERN FOREST (FORESTRY COMMISSION)

Mr. W. D. Russell of the Forestry Commission and his staff demonstrated Tintern Forest, some 5,000 acres in extent, now a part of the Dean National Forest Park, including both hardwoods, especially oak, and conifers. It had been under Working Plans since 1915, with separate Working Circles for hardwoods and conifers since the plan of 1924–34. The Second World War, emergency clear-fellings, shortages of planting stocks and labour, &c., had caused arrears and divergence from plan; but under Mr. G. B. Ryle's 1948–57 plan these arrears were being dealt with as far as possible. The first urgent objective was to

bring the thinning programme up to date. Some 80 per cent. or more of the 20–40-year-old conifers were cut for the Second World War, and perhaps 35 to 40 per cent. of all the timber suitable for felling.

The background of this ancient forest was a long history of hardwood coppice with standards, to suit charcoal-burning and travelling forges. The original conifers were introduced about 1850 by the Duke of Beaufort, and to-day what remained of them were mature or nearing maturity. Particularly where they occurred in mixture with oak and beech, they were of great value and fine appearance. The natural oak stands varied but represented now decades of gradual improvement, and certainly a great advance. In artificial regeneration of oak the Forestry Commission, contrary to some German experience, had found no better results from sowing than from transplanting; and the tree form produced by some French acorns that had been tried was very inferior to that from local seed.

The European larch planted in Compt. 80A in 1850–5 in mixture with older oak and beech were demonstrated by Mr. A. P. Long, Director of Forestry for Wales, who recalled thinning them heavily in 1914, 35 years previously. The early opinion that he had ruined them had been proved wrong, for they had responded well and were to-day of exceptional value and beauty. In Compts. 82A and B were seen two specially good plantations of 36-year-old Sitka and Norway spruce, of 1913. The volumes per acre appeared about equal, but some of the best judges among the visitors preferred the look of the Norway crop on a commercial basis; and there was a feeling that in the relatively light rainfall of this area it might be better to choose Norway rather than Sitka spruce for planting, pending more experience of final results.

The general impression was that of a very interesting forest, showing much improvement and promise in both hardwoods and conifers, in spite of wars, slumps, and inevitable shortages. The beauty of the older conifers was a good omen and an answer to the critics of the æsthetic aspect of softwood plantations.

GARNONS ESTATE (Sir Richard Cotterell, Bt.)

Sir Richard Cotterell, Bt., demonstrated his woods personally. Ash is the principal species and thrives all over the estate, growing fast and selling well. There is some exceptionally good oak also, in Caroline Copse. It is 130 years old, and mainly sessile. On these 12 acres there are over 20,000 cu. ft. of prime oak timber, of quarter-girth 18 inches and up, with an admixture of sycamore, elm, ash, sweet chestnut, hornbeam, beech, and birch. Elsewhere the European larch is very good, but as the soil is suited primarily to hardwoods there are few other conifers except in mixture with the young planted hardwoods. The mixture provides elasticity and the possibility of a change for economic or other reasons.

The estate is in the Wye valley, 8 miles west of Hereford, on Old Red Sandstone (Devonian), with an annual rainfall of 30 inches. The woods cover some 500 acres, of which about 380 acres, in two main blocks, are being dedicated by the owner under the current national scheme for permanent private forests. The balance of about 120 acres is in small woods of 2 to 10 acres, unsuitable for dedication; but the owner means to work them to the same standard of silviculture.

The woods used to be mainly coppice with standards, and pheasants were a major objective. 440 wild pheasants were shot in one day in 1935. Since 1934 the bias has been towards forestry, with game a secondary consideration. There are about 120 acres of mixed plantations under 15 years old, and the coppice is being converted into high forest. The owner manages the woods himself, with the help of an agent, head woodman, and 7 to 10 woodmen, some of whom work also on the Home Farm.

Very careful compartment records and costing accounts are kept. It was clear that the management was keen and enterprising, with bold experiment and initiative conspicuous.

Notes were provided on eleven particular stands which were demonstrated and discussed. Space allows reference to some of the major features only.

The natural regeneration of the ash is very good, in places, and is relied on where it appears appropriate and of a satisfactory type of tree. Deliberate working for natural regeneration can be more expensive and less successful than planting, in the owner's experience. Where he is planting ash, the owner is experimenting with a wide range of mixtures of the ash with conifers, and sometimes with oak and conifers. He favours, generally, a spacing of 5 feet in the ash rows, and 5 feet between the ash rows; corresponding figures of 5 or 6 feet in and between the conifer rows; and about 3 or 4 rows of pure ash alternating with 2, 3, or 4 rows of pure conifers such as European larch. (On the better soils Japanese larch grows too wild.) He aims at valuable intermediate yields from the conifers, and a few good conifers in the final crop; but mainly a final crop of ash at about 40 to 50 years, of a breast-height girth of some 36 inches, with sometimes an equal number of oak, about 40 feet apart, the best of which will grow on to over 100 years.

Brambles give trouble in cleaning. A motor scythe (Allen) promises substantial reduction in cleaning costs on certain types of ground. The owner believes firmly in securing and keeping a good crown on his young ash, maintaining its vigorous growth (if possible at 1-inch girth per year or 6 rings per 1 inch of radius), knife pruning to correct forking, and the study of superior races of ash.

The pruning is done with an ordinary knife at a half man-day per acre, in May, every second year, up to 12 feet. It may cost about 7*s.* 6*d.* per acre. An American 'Point Cut Pruner No. 1' (the smallest model; not a Forester Pruner), as illustrated in the top photograph facing p. 76 of the *Quarterly Journal of Forestry*, vol. xliv, No. 2, April 1950, is used for green brashing of larch, to check brambles (*Rubus*), and avoid canker.

Some of the visitors thought that the ash on the poorer ash land owned by the Forestry Commission behaved differently. It forked badly unless kept crowded, recovered from crowding unless kept crowded too long, and was not induced to avoid forking if it was pruned. They also held that experience with oak suggested it should be kept close until of adequate height, and then freed to put on girth; and its crown branches should not be allowed to grow big enough to form heartwood, lest when killed by the canopy above they admit disease. The few oak sample plots in the country suggested that oak can be forced up by close stocking, unlike the conifers which cannot be so forced into height growth. If veneer timber was to be a major objective for oak in future, perhaps about 20–2 feet would be an adequate length for the main bole, and more girth would be preferable to greater length. The utilization of the Garnons ash is roughly as follows:

1st size: Scout poles or beansticks.
2nd size: Hoopwood, if of good quality; otherwise agricultural.
3rd „ Tent pegs, handles, &c.
4th „ Sports goods from the butts; handles from above the butts.
5th „ Carriage work.

Inferior material of the four larger sizes is converted and creosoted for estate work, or goes to firewood. As creosoted rails in estate fencing the ash lasts 30 years. Summer felling is avoided. Beetle damage is averted by extracting by early February or March.

Whatever is to be attributed to the soil and other natural advantages enjoyed by the Garnons ash, it was evident that it flourished and under good management gave a good

return on a relatively short rotation. When the owner's silvicultural experiments are older, the results should be even more outstanding and interesting.

TECHNICAL DISCUSSION

On the evening of 6th October, Mr. Sangar, as Chairman, suggested a discussion of the best forestry technique for current conditions in Great Britain, with special reference to what had been seen on the excursion, the high cost of planting and tending, and the case for and against pruning. Mr. A. P. Long hoped that private owners would handle much of the million acres of old woodland felled in the two world wars. He thought drainage was of first importance. Waterlogging brought in coarse grass, kept the soil cold, dissipated the humus, and slowed up the growth of young trees. In heavy soils one had to dig drains as a first essential. Coppice areas might include some thrifty growth, or very little such, or at worst nothing but weeds. He favoured using whatever useful natural regeneration there was, for example, groups of birch, and filling up the gaps completely, as cheaply as possible. Japanese larch, if the soil and other conditions suited it, was very useful in this respect, because it smothered weeds quickly and gave early returns from thinnings. (One must beware of natural regeneration of ash, coming up like mustard and cress in places where it had no future as a saleable product.) In smaller shaded gaps Douglas fir, grand fir, *Thuya*, or *Tsuga* were possibilities. The private owner might go for quick returns, legitimately, leaving slower returns to the State forests. Where the ground carried nothing but weeds, especially if there were lop and top, sheltering rabbits, he knew no better course than complete clearing and planting. Groups and strips had been tried unsuccessfully, giving incomplete cover and calling for costly later clearing of the balance of the rubbish. Sir Gerald Trevor referred to £40 per acre for planting as very discouraging. He felt wider spacing could reduce the cost, e.g. Sitka spruce at 6 ft. × 6 ft. instead of 4 ft. × 4 ft. He never planted larch closer than 6 ft. × 6 ft.; and mentioned larch at Northampton in lines 8 feet apart, with the plants 6 feet apart in the lines, avoiding the first thinning or the lack of it which ruined larch at ordinary spacing. Mr. M. V. Laurie said the results of spacing experiments were under analysis. On moorland a wide spacing led to long checking; and one or two casualties caused a bad gap, perhaps covered with bracken, which might not fill for 30 years. Mr. Bruce Urquhart said that where pigeons were apt to damage spruce tops, a wide spacing might be disastrous. He preferred extraction rides at every tenth row. Fencing costs had to be remembered. Sir Richard Cotterell thought extraction and accessibility were important factors, and asked if a spacing of 5 feet in easier places and 9 feet in difficult ones might be suitable. Mr. A. H. Popert thought elimination of the rabbit and grey squirrel, and fencing, were usually essential to natural regeneration. He endorsed an earlier warning against prolific ash with no future. Mr. M. V. Laurie instanced the good effect of fewer knots on the wastage in using softwoods, even for boxes, and favoured pruning if the cost were reasonable. One must weigh the economy of wider spacing against the cost of pruning which might be essential if one planted widely. Mr. C. W. Scott favoured pruning the better trees early, if at all. Mr. C. A. Connell was against high pruning except for peeler logs or other special cases; and thought genetics might avert the need for pruning, by producing trees of a fine branch habit. Mr. John T. Smith believed firmly in growing quality rather than quantity of timber; and doubted whether pulp and plastics would be an attractive outlet for poor quality wood. Sir Harold Glover pointed out that in Austria the better qualities were produced without pruning, by a long rotation suitable only for the State, not private owners. He mentioned that in the Himalayas the spacing for certain planted conifers was 6 feet in accessible and 8 feet in

more remote places. Mr. Riddoch thought the demand for clear timber was not a large proportion of the total demand.

Mr. R. W. V. Palmer spoke on the importance of estate or compartment records, or registers of costs and results, and had found the Garnons registers extremely interesting. Mr. H. R. Blanford endorsed the value and importance of records, in the interests of continuity.

Mr. Sangar summed up the opinions expressed and gave his own. He felt there was a general trend towards wider spacing, to suit new conditions, and spacing trials were important. He believed in using natural regeneration where a valuable species was appearing and promised a profitable crop. He felt brashing at least was essential, and the economics of pruning deserved examination. He recognized the need and value of a plan of operations, to secure continuity of management, in forestry as in any other business.

REVIEWS

Dartington Hall Woodlands, Ltd.: An Examination of the Accounts for the Year 1947–8. By W. E. Hiley

Review by J. J. MacGregor

THIS statement of the annual financial accounts of the Dartington Hall woodlands reveals the difficulty of estimating profit on any business which, for one reason or another, has not attained the status of a going concern; in forestry there is the complication that timber sales may represent capital as well as income. These woodlands, like those on all other estates in Britain, are at a stage of rebuilding after the inroads made by requirements of emergency and war. It is not surprising, therefore, that the trading result is loss in the post-war years.

The author hopes that the publication of the accounts 'will provide evidence which can be used both in the fixing of fair control prices for woodland production and in assessing the influences which subsidies might have in enabling private forestry to continue as an economic enterprise'. These two purposes have in effect the same fundamental aim, and the fact that prices are now decontrolled in no way removes the need for objective evidence of this kind. The author is careful to point to the limitations of evidence based on one year or on the results from one estate. The staffing of the Company, too, shows that the woodlands are intensively managed and at present minor forest products provide the bulk of sales.

The introduction of the paper mentions that two methods of profit estimation are recognized in forestry and goes on to describe a third method. The first method is based on the history of a single plantation, for which the rate of interest earned can be calculated at the end of the rotation. Even, however, where relevant data can be obtained, the usefulness of the conclusions is likely to be vitiated by changing economic environments and cost to price ratios. The second method is based on the conception of 'the normal forest', where the objective is to develop a going concern on a sustained yield basis. The criterion or objective of the sustained yield can be heavily criticized as being unrealistic. At the International Forestry Conference held at Helsinki in 1949 the idea of a 'progressive yield' basis was put forward as more appropriate, while in America C. W. Stillman has described the economic goal of 'sustained value'. In Britain, in view of the war depredations, the idea of the normal forest will for a long time have to remain a wishful thought.

The third method, employed in the paper, takes into consideration the opening and closing valuation of the capital stock, as well as the trading result, in arriving at profit. While it is true that most private woodlands are likely to show trading losses for many years to come, at the same time an increase in the capital value is taking place.

The Company, which leases just over 1,700 acres of effective woodland, has the disadvantage that these are scattered and that geographically they are remote from large markets, although to some extent these factors may be offset by favourable soils and climate. It is estimated that it will take about 40 years to attain a 'normal' forest, with more or less evenly balanced age-acreage blocks of trees.

The valuation of the mature timber is based mainly on sale value, and each of the 250 sub-compartments is separately assessed. The book values are, however, reduced from

this basis, to allow for the fact that it would not be appropriate to fell all the mature timber at once and because the cost of replanting is paid out of the sale price. A physical revaluation of old woods should be made every 10 years, and in the intervening years an increment borer can give guidance about rates. For old oak this was found to average $1\frac{1}{2}$ per cent. New plantations are valued on estimated average costs of planting, and increased at a rate each year which will bring them up to their expected value when saleable.

At Dartington these principles have been applied since 1934: new plantations have been valued at £10 per acre; increment values have never been more than $3\frac{1}{2}$ per cent. per annum; while the book value of felled areas has been deducted. It has not been possible, owing to the war, to make the physical revaluation every 10 years, and thus the current valuation and increment, owing to changing costs and prices, are much too conservative. However, an adjustment was made to meet these charges.

A feature of the financial results is the high rate of gross sale, at £11 per acre of woodland, an amount which would be high even for a fully developed forest. Some of the more important sales, however, include the formerly less orthodox sale of Christmas trees and nursery plants. Other items which appear in the income are sawn timber and jobs. However, these approximately balanced and thus added nothing to net income.

The general conclusion from the examination of the data is set out by the author as follows: '(1) If an appropriate allowance were made for the increase during the year in the value of the woods, the Company would show a small profit on its Profit and Loss Account. (2) As this profit is much less than the net profit from the nursery and Christmas trees, the woods by themselves show a loss. (3) This loss is so large that even if the control prices of timber and pit props had been raised by 42 per cent., there would still have been a loss.'

The choice of an increase of 42 per cent. as an appropriate amount to make the cultivation of conifers reasonably profitable on good land had previously been argued by the author in *Forestry* (vol. xxii, No. 1, 1948: 'A Basis for Fixing Controlled Prices of Round Coniferous Timber'). The effect of such increases on the rate of increase of the valuation of young plantations is suggested in this article, along with the direct effect on sales. The outstanding fact in the current economy of the company was that without the profit from the two successful sidelines the loss would have been considerably heavier. These ideas are fully supported by the Balance Sheet, Profit and Loss Account, Analysed Trading Accounts, and the Detailed Analysis of Profit and Loss Account for the full year ending 31st August 1948, and for the previous 8 months of 1947.

The author describes the financial results as very discouraging. His main general conclusion is that with the current high level of wages, intensive forestry in the circumstances at Dartington is not profitable. He hopes, however, that in 3 or 4 years' time pitprop production will increase fivefold, and with an increased price for these props the cultivation of the woods might then pay its way.

The recent removal of price control should give an early indication of the level at which prices will settle. One of the chief lessons which emerges from Mr. Hiley's analysis is the need for woodland management to be sufficiently flexible or adaptable to take advantage of special and local markets, such as those for Christmas trees or nursery stock. At present and for some time to come the erstwhile roles of major and minor saleable forest products are likely to be reversed.

The Forests of Present-day Finland. By Yrjö Ikvessalo. Communicationes Instituti Forestalis Fenniae, vol. xxxv, 1949.

Review by H. M. Steven

THIS publication of 56 pages crystallizes information about Finland's forests. Finland has been a pioneer in the field of systematic stocktaking, both in resources and utilization. The first National Forest Survey was carried out from 1921–4 and the second from 1936–8. The methods and results have been published in volumes ix, xi, xiii, xv, xxii, xxviii, and xxx of *Communicationes*. The summarized data in the present publication are based on the 1936–8 survey, but recalculated to allow for her loss of 10,743,000 acres of land to the Soviet Union. The third National Forest Survey will probably be carried out in 1951–3.

Finland extends from latitude 60° to 70° N. Except for limited areas in the north and north-east, the topography is one of low relief; it is a mosaic of forest and lake, the forest predominating, with relatively small areas of cultivated land and open swamp, except in the extreme south. The forest soils are 73 per cent. mineral, podsolic with glacial parent material, and relatively poor, and 27 per cent. peatlands. Finland's innumerable watercourses are the basis of her methods of extraction of timber; there are 25,000 miles of maintained floating channels. The loss of the exit of her biggest water system area in Karelia to Russia was a severe blow, making it necessary to increase truck and railway transport there.

The method of survey was a combination of line survey and circular sample plots. In the last survey there were 62 survey lines, spaced about 8 miles apart, running south-west to north-east, and extending to 15,500 miles.

Of the 71 per cent. of the land area classed as forest, 56 per cent. is rated as productive and 15 per cent. as poorly productive. On the basis of Cajander's types, the productive forest land is distributed as follows:

Types	*Southern half*	*Northern half*
	%	%
Grass-herb	0·9	0·2
Oxalis-Myrtillus	13·7	1·1
Myrtillus	41·4	12·8
Hylocomium-Myrtillus	0·0	8·7
Vaccinium	23·3	4·3
Empetrum-Vaccinium	0·4	13·5
Empetrum-Myrtillus	0·0	25·1
Calluna	3·4	3·2
Ericaceae-Cladina	0·0	14·9
Cladina	0·2	1·0
Productive swamp	16·7	15·2
	100·0	100·0

The largest area of productive forest land is in central and eastern Finland; the largest area of poorly productive forest land and waste is in the north.

Finland has few species of forest trees, but these are just what the world needs. Eighty-one per cent. of the forest area is conifers, 53 per cent. pine, and 28 per cent. spruce; while the 18·1 per cent. of broadleaved is made up of 16·8 per cent. birch, 1·2 per cent. alder, and 0·1 per cent. aspen; the balance is the cleared area.

One of the unexpected things a visitor to Finland learns is how long 'shifting cultivation' lasted. In southern Finland burning for cropping lasted until the end of last century, and much of the existing forest is on burned-over land. This and the slow growth in northern Finland explains the unbalance on age-class distribution. In southern Finland middle-aged stands predominate, 63 per cent. are in the 50–100 age class, and 25 per cent. under 50. In northern Finland only 6 per cent. are under 50, and 68 per cent. are over 100 years.

The total growing stock is 48,384 million cubic feet, 45·5 per cent. being pine, 32·2 per cent. spruce, and 18·8 per cent. birch. The stocking is often poor, partly due to adverse site conditions, and partly to overcutting on farm forests. The mean volume for the whole country is 903 cubic feet over bark per acre, varying regionally from 1,403 cubic feet in parts of central Finland to 429 cubic feet in the northernmost part of the country. In the southern half of Finland 68 per cent. of the growing stock is in the 40–80 age class and in the northern half 75·7 per cent. in the over 80 classes. The annual growth amounts to 1,441 million cubic feet, of which 41·9 per cent. is pine, 32·8 per cent. spruce, and 20·6 per cent. birch. The growth per cent. is 4·2 in the southern and 2·3 in the northern half of the country.

As regards silvicultural treatment of the forests in the 10 years before the last survey, it was estimated that 14·4 per cent. could be considered good and 50·8 per cent. satisfactory. There is great scope for improved silviculture.

Before the war the quantity cut was well within the annual growth, and this was so particularly during 1940–4. In the period 1945–7 more than the annual growth was removed, but there are considerable stocks not yet utilized; hence there will probably be a fall in the rate of felling. In this respect, therefore, the position is satisfactory: 31·4 per cent. of the cut goes as raw material for industry (of this, 52·0 per cent. to the saw-mill industry, 41·8 per cent. for pulp and paper, 5·0 per cent. for plywood, and 1·2 per cent. to other industries), 9·1 per cent. for fuel for industry, 32·9 per cent. for household use, 4·2 per cent. as exports of unmanufactured wood, 9·3 per cent. for means of communication, and 13·1 per cent. for other purposes.

The ownership of the forests is predominantly private, mainly as part of farms, and this is increasing because of resettlement on the land of peasants displaced when Karelia was absorbed into Russia and of ex-servicemen. The estimated distribution as at 1948 was: private 57·3 per cent., State 34·2 per cent., companies 6·8 per cent., communities 1·1 per cent., and the Church 0·6 per cent.

There are also short sections on forest administration and organization, forestry legislation, forestry education, and research. The publication is well illustrated by maps, diagrams, and photographs. The author is to be congratulated on a well-presented and informative publication.

NOTICES

The Forest Economy of Three Private Estates in Great Britain. By J. J. MacGregor (Forest Economist, Dept. of Forestry, University of Oxford). Imperial Forestry Institute, Oxford, Institute Paper No. 25. 1949. 7*s.* 6*d.*

THE author presents here a valuable analysis of the financial results from the woods of three anonymous private estates in Great Britain, one being in eastern Scotland. In two cases the analysis is based on 30 years of annual reports, and in the third case on unbroken annual reports from 1884. The chief timbers mentioned are beech and larch. The great effect of a good local market is brought out. The author relates his results to his previous studies published in *The Journal of the Royal Agricultural Society* in 1937 and in *Forestry*, vol. xx, 1946, and to W. E. Hiley's article in *Forestry*, vol. xxii, No. 1, 1948, 'A Basis for Fixing Controlled Prices of Round Coniferous Timber'. The general effect of the study is encouraging, especially as to the results from well managed woods once they are established.

The Establishment of Vegetation on Industrial Waste Land. By R. O. Whyte and J. W. B. Sisam. Commonwealth Agricultural Bureaux, Joint Publication No. 14. 10*s.*

THIS valuable summary, illustrated by some very striking photographs, refers to England, Scotland, Wales, the U.S.A., Germany, France, S. Africa, and Cyprus, briefly in some cases, but with useful references for further reading. It is a timely publication in view of the effects of open-cast mining in England and the need to deal with the problems it creates.

Quality of Second-Growth Douglas Fir and Suggested Means of Improvement. By Benson H. Paul, Chief, Dvsn. of Silvicultural Relations, Forest Products Laboratory, Madison, Wisc., U.S.A. (Forest Service, U.S. Dept. of Agriculture). Forest Products Research Society, 1950 preprint.

THIS is a preliminary copy of a report which was due to be presented at Portland, Oregon, in June 1950. Those familiar with the author's previous work on pines and hardwoods will read with very great interest his latest views on Douglas fir. They will be glad also that the Forest Products Research Society of the U.S.A. is listening to sound silvicultural advice, and hope that silviculturists in the United Kingdom will not fail to study the utilization aspects of their labours to grow useful trees. On the Pacific coast an age of 160 years is taken as the boundary between immature second-growth Douglas fir and old-growth mature stands of the same species, often 500 to 600 years old. Maturity, of course, is a relative term. Consumers in Britain are familiar with the great virtues of clear old-growth Douglas fir from Canada and the U.S.A. Apart from dollar difficulties the supplies of such lumber are limited. Younger crops will form an increasing proportion of the available supplies. With good silviculture, such as the author advocates, there can be obtained, in a shorter time than nature used to take, a satisfactory quality of timber, attractively dense, strong, and clear of knots. The author writes: 'It will be advantageous to start with closely stocked stands, so that growth can be regulated and a desirable growth-rate maintained by thinnings. The trees must be pruned to remove lateral branches

that persist and form loose knots in lumber and veneer. Pruning will be accomplished more quickly and the pruning wounds healed more satisfactorily if the pruning is done when lateral branches are very small. . . . Forest management, therefore, should aim not for the largest trees in the shortest time, but rather for a maximum, per acre, of high-quality products over a reasonable rotation.'

This is sound advice. In the United Kingdom, with its relatively rapid conifer growth-rate, it is essential to study these questions, including the mechanics and economics of pruning.

State Control of Private Forestry under European Democracies. A survey of developments in eight countries of Western Europe in the decade 1938 to 1948. By M. L. ANDERSON. Clarendon Press, Oxford. 1950. 17*s.* 6*d.*

IT is salutary to see ourselves as others see us. The following extracts from the review of this book in the U.S. *Journal of Forestry* for July 1950, by Hardy L. Shirley, New York State College of Forestry, are therefore reproduced with grateful acknowledgements.

'Anderson's review of recent developments in state control of private forestry in various European democracies comes at a particularly strategic time for both Great Britain and the United States. The countries studied—Belgium, Denmark, Finland, France, Netherlands, Norway, Sweden and Switzerland in common with Great Britain and the United States—were strongly impressed with the need for substantial timber reserves during wartime. . . . He makes five specific criticisms of British practice as a result of his study of regulation in other countries:

'1. A commercial co-operative association of forest owners should be formed to counteract present apathy towards the dedication scheme. Two organizations are desirable, one for small owners and one for large owners.

'2. Adequate attention should be given to the small woods and shelterbelts.

'3. Government in its control of home-grown timber prices should set prices more nearly in relation to the costs of production than it now does.

'4. Regulation should be placed on a more nearly voluntary basis as it is in Scandinavia rather than on a strict compulsory basis.

'5. An adjustment of tax rates should be made so that rates are in keeping with the productivity of the forest land.

'This study forms a splendid sequel to R. S. Troup's book, *Forestry and State Control*, that came out in 1938. It should be required reading for those concerned in formulating industrial, state, and national forest policy.'

The position and prospects of the Dedication Scheme have improved since Dr. Anderson wrote his book and the above review was drafted. There is more urgent need than ever for efficient co-operation between the State and private ownership and enterprise, on terms fair to both.

Y Coedwigwr ('*The Forester*'). The yearly magazine of the Forestry Society, University College of North Wales, Bangor. Vol. I, No. 2. 1949–50. 2*s.*

A COMPLIMENTARY copy has been received and sets a good standard, with articles on forestry in the United Kingdom, Norway, Nigeria, and North America. The Secretary of the Society would be glad to hear from old students not already on the circulation list.

CONTENTS

Tree Breeding and Seed Supplies in North-west America with special reference to Douglas Fir (*Pseudotsuga taxifolia* Brit.). By H. G. CHAMPION 69

Interim Note on a Thinning Study in Young Pine in East Anglia (*Pinus sylvestris* L. and *Pinus nigra* var. *calabrica* Schneid.). By F. C. HUMMEL 78

The Soil Conditions which determine Wind-throw in Forests. By W. R. DAY 90

An Example of Periodic Variation in Forest Sampling. By D. J. FINNEY 96

The Resistance of Wood-rotting Fungi to Desiccation. By W. P. K. FINDLAY 112

Society's and Other News 116

Annual Excursion of October 1949, Based on Hereford 117

REVIEWS

Dartington Hall Woodlands, Ltd. An examination of the accounts for the year 1947–8 (W. E. HILEY). By J. J. MACGREGOR 123

The Forests of Present-day Finland (YRJÖ IKVESSALO). By H. M. STEVEN . 125

NOTICES

The Forest Economy of Three Private Estates in Great Britain. By J. J. MACGREGOR 127

The Establishment of Vegetation on Industrial Waste Land. By R. O. WHYTE and J. W. B. SISAM 127

Quality of Second-growth Douglas Fir and Suggested Means of Improvement. By BENSON H. PAUL 127

State Control of Private Forestry under European Democracies. By M. L. ANDERSON 128

Y Coedwigwr ('The Forester') (University College of North Wales, Bangor) 128

Printed in Great Britain at the University Press, Oxford, by Charles Batey, Printer to the University